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Cognitive Processes and Learner Strategies in the Acquisition of Motor Skills

by

Robert N. Singer and Richard F. Gerson

FLORIDA STATE UNIVERSITY

Tallahassee, Florida 32306

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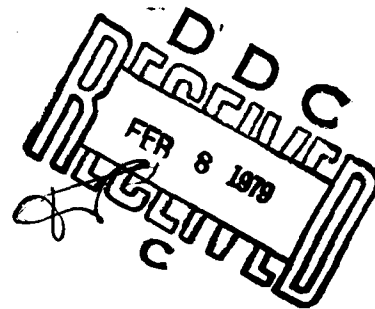


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to facilitate the enumeration of learner strategies and their relation to categories of motor tasks, which, in turn, would improve task analysis and instructional procedures. Finally, several experiments were described that are currently being conducted to test the effects of learner strategies on motor behavior. ↲

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COGNITIVE PROCESSES AND LEARNER STRATEGIES IN
THE ACQUISITION OF MOTOR SKILLS

Robert N. Singer
Professor and Director
Motor Behavior Resource Center
Florida State University

Richard F. Gerson
Project Coordinator
Motor Behavior Resource Center
Florida State University

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INTRODUCTION

The process-oriented approach to the study of motor skill acquisition (Pew, 1974) has gained increasing popularity in recent years, with focus on the content of the input. Of special consideration are those factors that would lead to movement selection and initiation, or the reproduction of specific output actions, such as the parameters for movement execution and completion. Investigations in this area have not been designed to identify the internal processes which underlie the learning of motor skills, or that may be associated with the production of a motor response.

Thus, such research has reflected little concern for the cognitive aspects of skill acquisition, e.g., learner strategies. In addition, the learner's overall personal involvement, i.e., the notion of individual differences, in the activity has also been neglected. The lack of consideration given to the cognitive operations used to learn and to perform a skill, and our recognition of their importance, has led to our present conceptual and research orientation.

Rationale

It is our contention that cognitive processes (control processes) and learner strategies contribute a

much greater role to skill acquisition than previously realized. The assumption is based on the fact that real-life psychomotor tasks are more complex than the typical motor tasks performed in a laboratory. Real-world skills do not only require learners to produce refined responses to specific cues, but they: (a) take a considerable amount of time and effort to learn well; (b) may impose demands for instantaneous decision-making to unpredictable cues; (c) may involve the use of appropriate and effective tactics and strategies to solve both familiar and nonfamiliar problems; (d) may require the proper control over emotions for use during stressful or arousing situations; and (e) may make a demand for a series of continuous or sequential behaviors that culminate in performance determined as appropriate or inappropriate according to established criteria.

Norman (1973) has taken a similar viewpoint with regard to cognitive skills. Verbal material is best learned when new knowledge is integrated into previous memory stores through strategies. The development and production of a learning strategy occurs through a series of cognitive operations that the learner performs. The use of these processes is an indicant of the degree of learner involvement in the acquisition of both motor and verbal skills.

For these skills to be learned and to be performed well, a learner must invoke a series of cognitive operations. The highly skilled learns to activate some and suppress others, depending upon environmental circumstances. A conceptualization of these cognitive processes has been described elsewhere (Singer & Gerson, in press), with the intent of using this material to determine the strategies a trainee would invoke during the learning of various categories of psychomotor tasks. Such an approach has proved moderately successful with verbal behaviors (Brown, in press), but has been neglected relative to motor skills.

Although motor skills have been less studied compared to verbal skills, there remains a reasonable degree of uncertainty in each as to which strategies, introduced in what manner, will lead to enhanced acquisition, retention, and transfer potential for related learning tasks. The general aim of strategies research in both behavioral domains is to have learners focus on the principles of strategy usage, and the various situations in which rules may be applied, more so than on the learning of specific content material. It would be hypothesized that information and skills could then be acquired in new, but related situations.

Essentially, our hypotheses are that:

(a) alternative strategies need to be identified as to their relative potential impact; (b) strategies should be introduced to enhance the trainee's effectiveness in learning specific content; (c) trainees need to know which strategies will work in particular situations; and (d) trainees should retain more and transfer learning capabilities better without external directions, guidance, or prompts under desirable circumstances if the learners understand how and when to use strategies. These notions should hold true, regardless of content.

To summarize our position, we believe that: (a) cognitive processes are much more involved than heretofore realized in the acquisition of complex motor behaviors; (b) most research has been undertaken on relatively simple motor skills, involving minimal information organizational strategies and demands on decision making; (c) there is a need to determine which learner-initiated strategies are most relevant and effective for the learning and retention of categories of psychomotor tasks, which will lead to enhanced transfer, and indeed, are amenable to learning; (d) learners need to teach themselves to use their capabilities to develop strategies to ready themselves to learn, to self-monitor their strategy utilization in the acquisition and performance of various kinds of skills, to retain the strategies and self-regulatory

techniques over time, and to use strategies to problem solve and to adapt to situations (transfer) with minimal guidance; and (e) it is most meaningful for instructional purposes to determine those processes that are under the control of the learner, and which strategies are available for him/her to select from.

The enumeration of processes which may be under the control of the learner can lead to a more thorough analysis of potential alternative strategies that the learner can employ to meet task demands. In turn, this information can provide a meaningful basis for instruction designed to assist learners in the development and the selection of the best strategies applicable to the acquisition of different types of tasks. Instruction would then proceed at a more rapid pace, and be more economical, because the strategies which are most relevant and most effective for the learning of categories of psychomotor tasks would have been determined. Ultimately, the ideal learning environment would be one in which strategies were self-generated by learners rather than externally imposed by instructors.

Format

This report contains an analysis and interpretation of cognitive processes and learner strategies, with implications for the acquisition, retention, and transfer

of motor behaviors. Much of the literature reviewed is from the cognitive psychological area, out of necessity. The presentation of material is sequenced as follows.

The nature of cognitive processes is interpreted from different perspectives, with an indication of the type of potential control each process can exert over motor learning. Real and hypothesized mechanisms in the nervous system are specified, with associated unique control processes and functions. Cognitive activities are described at a highly theoretical (technical) level as well as in a pragmatic manner. Differences in processing capabilities among people are briefly alluded to, although there is a greater need to explore the ways individuals vary in the manner in which they analyze situations and respond to them.

A discussion on the many interpretations of what is meant by the term, learner strategies, follows the one on cognitive processes. The relationship of specific externally-imposed or self-initiated learner strategies with particular cognitive processes is suggested with implications for instruction and learning. A mechanism-process-strategy conceptual framework provides the basis for the ideas advanced in this report.

Literature is then reviewed with regard to strategies and their potential to influence skill acquisition,

retention, and transfer. Very little literature is available on the generalizability of strategy usage, i.e., the transferability of them across performance in similar tasks. Evidence is increasing in the cognitive area with regard to the effectiveness of certain strategies as an aid in the acquisition and retention of verbal material.

The focus of the report is then directed toward the nature of psychomotor tasks and possible classification schemes. Those developed by other scholars are reviewed briefly, and a new one is proposed by us with the intent of maximizing the deployment of learner strategies, be they instructor-provided or trainee-initiated. Particular strategies are described as they might be most effective for the learning/performance of categories of psychomotor tasks. Direct and extrapolated research findings, as well as intuition, serve as the basis for this material. In reality, the task and strategy classification scheme demonstrates the need for much more research to support or invalidate the assumptions made.

COGNITIVE PROCESSES IN MOTOR SKILL

The formulation of a model of motor behavior, with heavy emphases on cognitive processes, has been described

in our first technical report, and provides the framework for the following material. To repeat, our basic thesis is that a great deal of information processing goes on when people attempt to learn complex motor activities. Much of it can be under the control of learners. The desirability of exerting deliberate conscious control will depend on many factors. One of the primary differences between the highly skilled and the lesser skilled is the degree and type of conscious involvement prior to, during, and following motor performance. Therefore, conscious focus and intervention at a particular stage must be determined according to task demands, personal level of skill, and ultimate objectives of an instructional program.

Interpretations

The term cognitive processes, or cognitions, has been defined in many ways. In fact, it appears that each researcher who uses the term provides a personal definition for it (e.g., Battig, 1975; Hunt & Lansman, 1975; Neisser, 1967; Norman & Rumelhart, 1975). These numerous definitions can become confusing, considering the different contexts in which the term has been applied. For this reason, and for purposes of clarity in relation to this work, we offer the following definition: a cognitive process is a control process

which is a self-generated, transient, situationally-
determined conscious activity that a learner uses to
organize and to regulate received and transmitted
information, and ultimately, behavior. Conscious
control processes operate serially and in stages.
Those that operate subconsciously, as with higher levels
of skill, can operate in parallel with a conscious
control process.

Many conscious control processes can be relegated
to a sub-conscious level of control. This is what
occurs when highly skilled behavior is initiated in
complex motor activities. And, in the case of initial
information contact to long term memory without attention,
consciousness may not be present in a person at any
level of skill. A person can exert many forms of
control to manipulate information and the effectors,
nonetheless, thereby directing behavior. However, the
person does not totally influence any situation, nor
does the reverse probably happen. Whereas behaviorists
might lead us to view human behavior as passively
controlled by situational dictates, cognitive psycho-
logists would suggest that people actively control their
environments. The truth probably lies somewhere in a
middle position. Behaviors are not produced without
cues or stimuli, and these behaviors are directed

accordingly. But all people do not respond similarly to the same events, thereby demonstrating some degree of self-determination. In a sense, associationistic behaviors are indeed developed, but in a person's own way.

The interaction between the person and the environment is considered to be the foundation of cognitive psychology (Estes, 1970, 1975). Neisser (1967) elaborated on this view by suggesting that the focus of cognitive psychology is on the processes by which sensory input is transformed, reduced, encoded, stored, recovered, and used. The specific subject matter which is operationalized for investigative purposes encompasses mental states and processes (Butterfield & Dickerson, 1976). Several processes associated with cognitive behavior are perception, information representation in memory, use of knowledge (Norman & Rumelhart, 1975), sensation, imagery, retention, recall, problem-solving, and thinking (Neisser, 1967). The manner in which a learner employs these various processes, in relation to personal cognitive capabilities for the efficient use of information, in activities such as comprehension, listening, and reading, is the major determinant of individual differences in the acquisition of skill (Battig, 1975; Gagné, 1967; Marteniuk, 1974; Reitman, 1969; Simon, 1975).

Differences in skill level may be better understood with a contrast of beginners and advanced performers, and how they utilize information to formulate behavioral responses. A beginning learner may not know which situational cues are relevant or irrelevant, and process several cues as individual inputs. This would result in an increased short-term or working memory load and a decreased capacity to process additional information that might be present and useful, for little organization of the information has taken place. The beginner would probably be unaware of how to use the appropriate control processes for the transmission of information through the hypothesized mechanisms of the human system. Therefore, a motor response based on the selective use of much available information would be erratic since the manner in which these cues were processed would require that they each be retrieved separately. In contrast, a highly skilled performer could abstract the commonality among the inputs and employ an encoding strategy for processing this information.

Encoding refers to a transformation of information from a general to a more abstract representation to facilitate storage and retrieval. Since the cues would be processed as a unit, more capacity becomes available to deal with new stimuli which can be used to update any

response requirements. Consequently, this performer will emit efficient motor behaviors because of the quality of the encoding of the cues, and the more efficient retrieval of those cues (cf. Tulving & Thomson, 1973). Thus, the cognitive processes which a learner applies to the processing of information can account for many of the differences observed between skill levels.

Processes and Functions

Table 1 contains a description of a number of cognitive processes that can be associated with particular mechanisms. We define a mechanism as a real or hypothesized "location" or "structure" associated with the nervous system in which specified unique control processes and functions occur. Possible functions of the processes are also described in Table 1.

Cognitive processes such as these are ongoing operations (Hunt & Lansman, 1975; Norman & Rumelhart, 1975) which the learner employs to enhance the acquisition, representation, and utilization of knowledge in memory. Other researchers have interpreted cognitive processes as controlling factors in the sequence of serially or hierarchically organized behaviors, similar to our

Table 1
The Conceptual Relationship of Mechanisms, Potential
Cognitive Processes, and Functions in
Complex Motor Behaviors

Mechanisms	Cognitive Processes	Functions and Purposes
1. sensory storage*	receive.....	briefly hold information
	transmit.....	forward it to LTS for memory contact or directly to perceptual mechanism
2. perceptual mechanism	detect.....	realize existence of signal
	alert.....	anticipate
	selectively attend.....	filter
	recognize.....	analyze features
		...match (present cues with stored information)
		...make meaning of information
	transmit.....	forward information to STS for action
3. short term storage (STS)	rehearse and process information temporarily.....	retain information for immediate use and decision making
	compare.....	retrieve information from LTS for analysis, decision making, and attributions following feedback
	transform.....	organize (chunk)
		...make more functional space available
		...provide additional meaning

Table 1
(continued)

Mechanisms	Cognitive Processes	Functions and Purposes
	appraise situation.....	form performance and goal expectancies ...establish emotional state
	select programs from LTS.....	transmit programs to movement generator
	plan program execution.....	determine parameters (location, speed, direction, timing, amplitude, force, effort) in which program is to operate
	transmit information....	transfer information to long term storage to establish learning
4. long term storage (LTS)	store information permanently.....	make information available for future use, establish pertinence, aid in anticipation, expectancies, and perception
5. movement generator	initiate program for motor behavior.....	cue appropriate musculature to execute within response parameters
	initiate coronary discharge.....	alert sensory center of the brain, anticipate movement consequences

Table 1
(continued)

Mechanisms	Cognitive Processes	Functions and Purposes
6. effectors	receive command.....	execute observable performance
	activate feedback sources.....	provide information for future usage (comparison, recognition) by making it available for long term storage
		...provide information to peripheral organs to help regulate ongoing behavior, to adapt behavior to situational demands
		...provide information to influence arousal and attitudinal states

*Cognitive processes do not directly influence sensory storage but can affect orientation to stimuli.

definition (Atkinson & Shiffrin, 1968; Johnson, 1974; Kausler, 1974; Scandura, 1977). Atkinson and Shiffrin (1968) have defined a control process as a transient phenomenon under the control of the learner, rather than as a permanent feature of memory, indicating that the use of a particular control process is situationally determined. The learner, by using both internal and external inputs, is capable of activating a particular control process so that selected items in the task environment receive more attention and rehearsal time than other items. This process would facilitate both the placement of these rehearsed items in memory and their retrieval at a later time.

However, this is a somewhat restricted view of control within an information processing system. Our viewpoint is that the control of motor behavior must be investigated beyond mere information representation. The cognitive control of such affective factors as arousal for stress adaptation, as well as the cognitive motivational factors of expectancies for the achievement of success related to causal reasons (attributions) for performance outcomes, must be placed into perspective with other cognitive processes which interact to direct and to regulate behavior. Thus, cognitions, or control processes, are involved in the learning and performing of

skills in various ways (e.g., for motivation, stress adaptation, concentration, relaxation, and performance expectancies, as well as information processing).

Table 2 simplifies much of material contained in Table 1. Here we can view a number of conscious activities that may operate somewhat sequentially in the learning of many psychomotor activities. As learners improve in their functional abilities with regard to these activities, we may assume that their skill level will improve as well.

The deliberate use of certain conscious control processes, or the capability of activating certain desirable subconscious control processes, will improve the functional capabilities of one or several of the hypothesized mechanisms in the human behaving system (cf. Belmont & Butterfield, 1977; Butterfield & Dickerson, 1976), such as increasing the capacity of the short term store by imposing an organizational structure to information being processed in that mechanism (Rigney, 1978). We are hypothesizing that a definite relationship exists between a particular mechanism and associated cognitive processes. Although a one-to-one relationship between a mechanism and a cognitive process may exist, it should be realized that several cognitive processes may also be associated with a given mechanism.

Table 2
 Explanations of Potential* Cognitive Activities and
 Functions in the Performance of Complex Motor Behaviors

Cognitive Activities	Function
1. convert instructional information	transform sensory information for movement representation
2. analyze relationships	recognize similarities between present and past tasks, situations, and experiences (transfer)
3. retrieve information	facilitate recall and recognition, and interpretations and decisions
4. understand task goals	form goal-image of intended performance
5. select cues	identify most relevant and minimal cues at any given time
6. establish personal goals and expectations	form performance expectancies
7. concentrate	focus attention, broad or narrow, depending on task demands

Table 2
(continued)

Cognitive Activities	Function
8. maintain optimal arousal (motivational) state	demonstrate conscious control over emotions where necessary
9. analyze nature of task	use fixed or adaptive behaviors as required
10. mentally rehearse prior to and/or after performance	strengthen images and potential motoric responses
11. adapt to stress	use control over emotions and environment where appropriate
12. analyze outcomes of decisions	consider costs and payoffs
13. make correct response decisions	consider amplitude, speed, location, distance, and accuracy
14. conserve energy	minimize effort to deter possible fatigue to maximize performance
15. evaluate ongoing performance (feedback) when appropriate and possible	monitor, regulate, and adjust performance

Table 2
(continued)

Cognitive Activities	Function
16. evaluate the results of performance (feedback)	use in future decisions in similar activities
17. attribute performance outcomes objectively	influence motivation, expectations, and performance in subsequent similar activities

*Any of these cognitive processes may be activated, depending on the skill level of the person, the nature of the activity, and personal intentions.

This relationship may be explained best by returning to the previous example of the performance difference between beginning and highly skilled learners. Both these performers use many of the same cognitive processes, perhaps at different levels of operation, to perform a skilled action, although the motoric actions of the advanced performer appear to occur more quickly, smoothly, and efficiently. It is as if performance becomes automatic with the development of skill, i.e., when information passes through a particular mechanism, the control processes necessary to work on that information are invoked without much conscious effort. Also, the skilled performer processes less information, taking into consideration perceptual, decisional, and effector redundancies. The appearance of automaticity is thus due to the application of appropriate control processes, operating optimally at the different information processing stages, along with the physical capabilities of the performer and the well-learned mechanics of the movement.

It seems, then, that the skilled performer must employ the appropriate cognitions associated with a specific cognitive stage, as well as possess the requisite physical qualities necessary, to yield superior performance. In contrast, the erratic and inconsistent performance of a beginner is due either to a lack of desirable

physical condition and movement technique, to a lack of cognitive processing capabilities (Chi, 1976), or to some combination of these factors. However, given performers with equivalent movement skills, superior performance will probably be evidenced by the person more capable of demonstrating appropriate control processes relative to changing task requirements (Battig, 1975).

Evidence for the mechanism-cognitive control process relationship would be provided by showing that the effective use of a particular control process for a given task reduces the amount of information which must be transmitted through that mechanism (cf. Butterfield & Dickerson, 1976). Due to the existence of this relationship between cognitions and stages of processing (Trabasso, 1973), the learner is capable of developing a hierarchy of processing skills corresponding to each mechanism (Schaeffer, 1975). The hierarchy is based on the complexity of the cognition or processing operations the learner must employ to transform and to transmit information through the system. Thus, as information passes through each stage (cf. Sternberg, 1969), the corresponding control processes must be adapted by the learner to meet the changing task requirements, so that information may continue to be transmitted through the system.

To integrate some ideas expressed so far, the

learner/performer may invoke cognitive processes to perceive the nature of the task in the context of the environment, to recognize similarities between the present task and previous experiences, and to selectively attend to and to identify the most relevant, yet minimal number of cues necessary for a response to occur. In addition, a person may utilize cognitive processes to enhance goal-expectancy formations, to enhance goal-image formation, or to finalize movement decisions made in the short-term store. Cognitions may be used to permanently store evaluative feedback and causal reasons of a performance outcome for future use. In conclusion, processes run sequentially and probably concurrently within the human system (especially when the second process can operate at a sub-conscious level), producing a profound effect on the learning and performing of complex psychomotor tasks.

Individual Differences

Although we have so far and will continue throughout this report to assume similarities among human systems with regard to the function of cognitive processes and strategies, differences do exist and they should be recognized. People vary in skill level, as has been noted previously, as well as in cognitive style, processing capacity, and reactivity to situations. It is

not in the purpose of this report to explore the many ways learners contrast, with implications for instructional purposes. We intend to do this in a future report. But we would be remiss here not to acknowledge some such differences, for certain strategies may be taught and used more effectively than others, depending on the "type" of person.

As to skill level, cognitive processes obviously function differently, enabling the highly skilled to use less capacity than the less skilled while being able to concentrate, to recognize appropriate cues accurately and quickly, to anticipate, to process information and make decisions rapidly, and to respond according to the demands of the situation more effectively than the beginner (e.g., Glencross, 1976; Jones, 1976; Marteniuk, 1976). This leads us to suggest that different cognitive processes are, and should be, activated or suppressed at certain points in the sequence of performing a skill. The more we can learn about the information processing capabilities and strategy deployment of the proficient performer, the more instruction can be improved for the beginner. Learning would then progress more rapidly toward desired end states.

Learners, regardless of skill level, may confront

tasks differently, depending on their cognitive style. Cognitive style is the manner in which an individual perceives the world, and processes perceived information according to personal capabilities. The general topical area has been labelled aptitude-treatment interaction (Cronbach & Snow, 1977). Such differentiations in psychological factors as field dependence and field independence would suggest the operation of different processes and strategies with regard to space-oriented situations (Witkin & Goodenough, 1977). Likewise, the existence of reflective and impulsive cognitive styles (Kennedy & Butter, 1978) suggests that different strategies may be used in the learning of tasks for persons identified accordingly.

Consideration must be given to differences in cognitive capabilities and styles among learners as to the imposition of any strategies. If the method for providing the strategies associated with learning a task is not compatible with the learner's capabilities and personal learning style, the acquisition of skill will probably be impeded. Since the desire of an instructional systems designer is to develop the most efficient way for persons to learn skills, individual differences among trainees must be taken into account in the establishment of an instructional program. Although,

in the next few sections, we will identify strategies that are generalizable across a range of tasks and trainees, it would be of great advantage to also be able to identify strategies that are unique to types of people. Strategies that can be used by learners to enhance the acquisition of skill even though their cognitive styles and capabilities differ, could then be implemented in a training program.

The acknowledgement of individual differences in cognitive processing capabilities and learning leads to a discussion of learner strategies, activities which enable the trainee to influence the way information is transmitted to and within the system. The processing of information is facilitated by the learner's activation and implementation of the appropriate strategies (Kausler, 1974; Norman, 1973). Several strategies may be available to the trainee, at any point in time, and the most productive one associated with a particular cognitive process should be adopted. It is apparent that strategies and cognitive processes are very much related in the acquisition, retention, and transfer of motor skills.

LEARNING STRATEGIES

One of the major problems in the identification

of strategies that improve skill acquisition is a universal definition of the term, strategies. It appears that many scholars provide their personal definitions to the term, possibly because no one previous interpretation was specifically suited to that researcher's particular work. Following the presentation of several interpretations of the word, strategy, we will provide our own interpretation relative to our purposes. In this definition, we have striven for clarity, brevity, conciseness, and consistency with previous literature, although we, too, may be guilty of adding verbiage to an already saturated field.

Interpretations and Definitions

An effective strategy has been described as the simplest and most efficient means of processing the information inherent in a situation (Newell & Simon, 1972). Rigney (1978) has stated that a strategy may be interpreted as signifying operations and procedures that a learner may use to acquire, to retain, and to retrieve different kinds of knowledge. Similarly, Bruner, Goodnow, and Austin (1956) defined a strategy as a pattern of decisions in the acquisition, retention, and utilization of information that serves to meet certain objectives, i.e., to insure certain forms of outcomes and to insure against certain others. To Gagné'

(1977), a strategy is a skill of self-management that the learner acquires to govern the processes of attending, learning, and thinking, while Gagné' and Briggs (1974) have suggested that a cognitive strategy is an internally organized skill which governs the learner's own behavior (cf. Richardson, 1978).

More pragmatically, Dansereau (1978) proposed a definition in which a strategy was considered to be a learner-based technique that, when acquired, would enable the individual to function effectively when confronted with the: (a) identification of important, unfamiliar and difficult material; (b) application of techniques for comprehension and retention of circumstances; (c) efficient retrieval of information under appropriate circumstances; and (d) effective coping with internal and external distractions while these other processes are being employed.

A conclusion drawn from an interpretation of the preceding definitions would be that a strategy which is developed by a learner in accordance with cognitive abilities and situational demands would be most effective in relating new information to previously obtained experiences (Bruner, 1961). Therefore, for purposes of our work, we define a strategy as a self-initiated or externally imposed means of utilizing information that

leads to decisions for purposeful behavior.

The Organization of Information

The manipulation and transformation of information are the major emphases in an information processing approach to learning. Within this framework the nature of a strategy is such that it enables a learner to form an organizational structure in which information can be stored and retrieved more efficiently (Bousfield, 1953; Bower, 1970; Mandler, 1967; Miller, 1956; Tulving, 1962). The composition of the order imposed by the learner depends on the inherent structure of the information and the cognitive capabilities of the learner (Gentile & Nacson, 1976). The fact that this organization is a result of the strategies employed by the learner to construct groupings, or relations, among the informational inputs to be learned leads to the inference that memory is a constructive and interactive process (compare the work of Bower, 1970; Mandler, 1967; Tulving, 1968). The process involves the learner actively searching for contextual relationships between the input and information stored in the system in order that incoming material can be transformed and recoded into newer and larger internal units (Gentile & Nacson, 1976).

While organizational processes have been frequently investigated in studies of verbal memory by examining the

input-output relationship of to-be-remembered material (Bousfield, 1953; Bower, 1970; Mandler, 1967; Tulving, 1962, 1968), the concept of organization has been virtually ignored by motor learning researchers. However, interest in the organizational variables which may affect motor skill acquisition has increased. This is evidenced by the concern for central or peripheral mechanisms of motor control (Keele, 1968; Kelso & Stelmach, 1976; Schmidt, 1975), the processing characteristics of spatial information (Jones, 1972, 1974; Kelso, 1977; Laabs, 1973; Marteniuk, 1973; Stelmach, Kelso, & McCullagh, 1976; Stelmach, Kelso, & Wallace, 1975), and the general encoding properties of movement information (Gentile, 1967; Nacson, 1974; Nacson, Jaeger, & Gentile, 1973).

Without providing a detailed description of these studies, it will suffice to say that the general conclusion has been that a learner imposed some type of structure on movement information so that it was learned and retrieved more efficiently. Performance was either dependent upon the experimental structuring of the task in which the totality of the relations among the movement cues is emphasized (Gentile & Nacson, 1976), or the subjective organization of the information, in which a structural context that corresponded to the learner's cognitive capabilities was imposed on the movement cues. Thus, the

development of the organizational strategies occurs in one of two ways.

External and Self-imposed Strategies

The behavioral processes which a learner uses to select and to govern attentiveness in a learning situation, the management of information storage and retrieval skills, and the construction of a problem solution (Gagné & Briggs, 1974), are directed by the implementation of associated strategies. The strategies may be external, instructor-imposed strategies, or internal self-generated strategies. These types of instructional strategies have been found to facilitate both verbal learning (Gagné, 1977) and motor learning (Roy & Diewert, 1975). A strategy which is imposed by the instructor on the learner may be designed to help the learner to acquire a skill as quickly as possible or to facilitate transfer effectiveness or problem solving in the future. While some imposed strategies may increase the rate of initial skill acquisition (Singer & Pease, 1976), they may not facilitate learning in transfer situations (Singer & Gaines, 1975). In certain cases, imposed strategies may be in competition with strategies already in existence within the learner (Pask, 1975). As such, acquisition, retention, and transfer of information can only be achieved when a learner becomes capable of self-generating learning

strategies, whether they have been initially externally directed or self-produced.

A self-initiated strategy is one in which the learner is capable of determining a procedure that is compatible with personal cognitive capabilities and cognitive style for the learning of a task or a category of related tasks. Strategy choice is partially determined by the particular situation (Bruner, Goodnow, & Austin, 1956), so a sound educational practice would appear to be to initially instruct learners in the use of learning strategies. Once a learner comprehends the nature of and the reasons for the use of particular strategies for the acquisition of skill, he or she should be capable of self-generating strategies in related future learning environments.

This is the ultimate outcome, as we see it, of any meaningful instructional or training program, to instill in learners the ability to develop their own effective cognitive strategies without external guidance. Following an instructional program, a learner should be able to generate the strategies which were taught by the instructor, even if the instructor is no longer present, when these strategies are necessary to perform certain tasks. Learners should acquire the ability to generate strategies which are congruent with their

cognitive capabilities for learning a task, or capabilities should be structured in a desirable direction.

Strategies, either self-generated or externally imposed, may be used by a learner in such ways as to attend to the learning environment, to manage information storage and retrieval, and to determine the requirements of a selected motor response. It may be concluded that strategies are selected and formulated to enhance the operation of a particular control process, and they are determined, in part, as a function of task requirements, problem content, and situational constraints. However, it is often quite difficult to actually observe the strategy a learner is using.

Bruner et al. (1956) contended that a strategy does not refer to a conscious plan for the acquisition and the utilization of information since neither a strategy nor a plan can be observed. Rather, a strategy is to be inferred from the pattern of decisions one observes in a problem-solver. Thus, the decisions a learner makes in regard to the selection of solutions for a problem can be interpreted as overt demonstrations of strategy usage.

The learning of a motor skill, or a verbal skill, reflects a problem which must be solved. The behaviors involved in acquiring both types of skills are very

similar (Adams, 1971) in that the learner must identify and interpret the problem, utilize strategies to facilitate the processing of information so a plan may be devised which will lead to possible solutions, produce those solutions, and then decide which is the best solution (Posner, 1973).

Additionally, Baldwin and Garvey (1973) have identified similar components of the problem solving process. A learner must define the general problem, relate the problem to previously experienced situations, identify the essential and relevant information in the problem, synthesize and formulate solutions, and decide on an appropriate solution through a verification procedure. It is apparent that these are the general cognitive behaviors a learner must invoke to solve a problem when information is transmitted through the system, i.e., to learn a skill, in order to produce a motor response.

Strategy-Process-Mechanism Relationship

It is important to identify the relationship between strategies and particular stages of processing (Trabasso, 1973), as we have in Table 1. The relationship among mechanisms, cognitions, and strategies can be more elaborately depicted in a representation of the mental operations which are hypothesized to occur

within any mechanism of the model proposed by Singer and Gerson (in press; Singer, Gerson, & Ridsdale, 1978). The interrelationship of these variables is presented in Figure 1.

For example, corresponding to the perceptual mechanism, several strategies may become operational by a person to filter relevant stimuli from the incoming information inherent in a situation. The learner may form strategies for anticipation, detection, and comparison of relevant stimuli to aid in the selective attention processes. By invoking strategies for recognition, feature matching, identification, coding, and classification, the learner is able to provide meaning to the input as a result of an elaboration of the information within the perceptual mechanism (Fraik & Lockhart, 1972; Fraik & Tulving, 1975). The learner uses the meaningful information to form clearer goal-expectancies and more realistic performance expectancies.

A more pragmatic example is provided in Figure 2. A baseball batter who must hit the ball (situation) has to narrowly focus or concentrate (strategy) on a small, finite number of cues, i.e., those that involve the ball. The process of selective attention has been associated with the perceptual mechanism. Many other examples of the situation-strategy-process-mechanism relationship could be determined. However, this one

1. a situation activates potential alternative strategies
2. a particular strategy influences a corresponding cognitive process
3. a particular cognitive process is associated with a corresponding mechanism
4. situation → strategy → process → mechanism

Figure 1. The relationship among strategies, cognitive processes, and mechanisms.

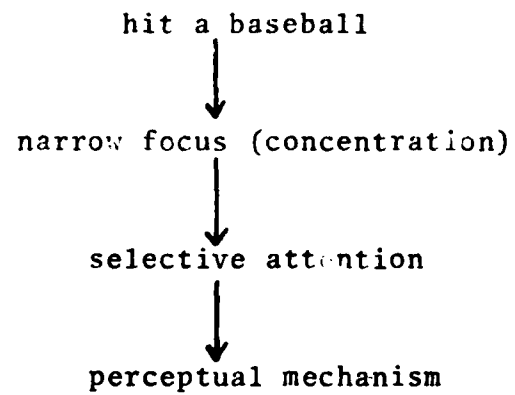


Figure 2. Relationship of variables with an example from baseball.

has been provided as a schematic of the practical utility of the model, with reference to only one of several mechanisms identified in the human behaving system (Singer & Gerson, in press).

Additional strategies may be available to be utilized by the learner so that information in short-term storage may be more elaborately analyzed (Craik & Tulving, 1975). Other strategies are also associated with the various control processes, and a learner may be capable of producing any of these strategies, although some learners are more capable of producing some strategies than other learners (Battig, 1975). When an individual chooses to move, and makes the appropriate decisions based on previous or recently acquired knowledge of how to perform a movement, that movement will occur because sufficient information was available in memory to formulate response requirements. If permanent storage of the information is desired, it should be transmitted to the long-term store and stored in such a manner as to promote convenient retrieval.

Strategies may be developed by the trainee to facilitate the hypothesized functions of the short-term storage system on information prior to its generation to long-term storage. Alternative organizational processes and rehearsal strategies may be applied by the learner to store

selected information more permanently and effectively, as shown in Figure 3. Other strategies are associated with the recall and recognition of information which results in the selection of a particular movement. Following that movement, strategies for adaptation and behavior regulation may be produced to aid in the processing of feedback to update response requirements of future movements.

In general, strategies are produced by an individual in conjunction with the information processing system to facilitate: (1) storage and retrieval of information; (2) a comparison of incoming information with referents previously stored; (3) transformation of information; and (4) decision-making as to the movement which will result in achieving the desired goal. The learner's appropriate use of strategies in these cases and many others is a significant determinant of motor learning and performance.

The manner in which a trainee develops and utilizes cognitions and strategies becomes evident in the acquisition rate and performance level of motor skills. An incorrect cognition, such as selecting the wrong motor program, or an inefficient strategy, is sufficient to retard the learning process and lower the performance quality. Training procedures must be designed so that appropriate

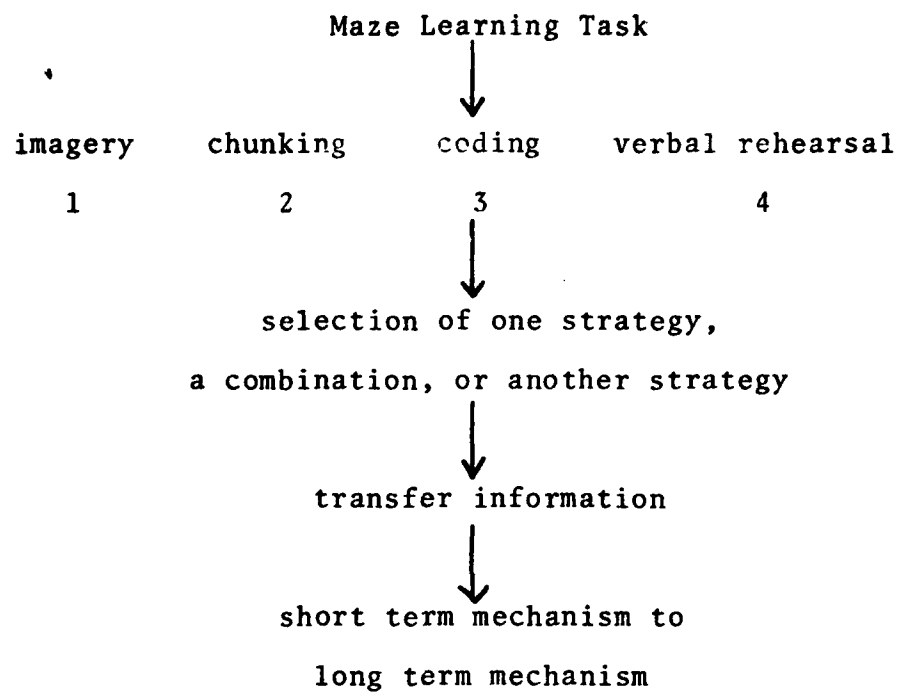


Figure 3. Relationship between one task and alternative strategies.

learning strategies can be identified, methods for enhancing the self-production of these strategies within a learner can be taught, and the content of these strategies may be made applicable to a wide range of motor behaviors. The conceptual orientation to motor learning discussed here so far is the logical first step in identifying several prerequisites related to skill acquisition, retention, and transfer.

ACQUISITION, RETENTION, AND TRANSFER OF STRATEGIES AND RULES

There is much to discover about the capacities, limitations, and idiosyncracies of human memory in the acquisition, retention, and transfer of skills. While previous research has been directed toward performance on memory tasks, it is only recently that interest has become focused on the learner's involvement during skill acquisition (see Brown, in press, and Flavell & Wellman, 1977 for reviews). However, little attention has been given to a person's ability to retain and to transfer information at a later date beyond a simple acquisition-test situation. This dearth of published literature is more evident with motor behaviors than with verbal behaviors.

The verbal learning literature is replete with studies

which have been designed for the investigation of a person's role in learning. Brown (1975, in press) has provided extensive reviews on the subject, and the findings need not be repeated here. The general conclusion drawn from those studies has been that a learner's active use of strategies appropriate for the task to be learned increases the rate and degree of skill acquisition (Belmont & Butterfield, 1973). Craik (Craik & Lockhart, 1972; Craik & Tulving, 1975) has reached a similar conclusion within the levels of processing approach to the study of memory. Different encoding instructions, which can be considered as similar to instructions in the use of various strategies, have led to differences in memory performance based on the meaningfulness of the processing. An essentially identical finding has been reported when a motor task was used as the skill to be learned (Ho & Shea, 1978; Shea, 1977).

Thus, strategies have been shown to have a facilitatory effect on the acquisition of both motor and verbal skills. One important question relates to the potential similarity of strategy effects across behavioral domains. In other words, will the same strategies that enhance verbal skill acquisition also facilitate motor skill learning, and the eventual retention and transfer of those

skills? A second question is, should strategies be taught for use with specific skills, or should instruction pertain to the general techniques and principles of strategy usage across task categories and domains? A third question pertains to the underlying processes associated with strategy usage and skill learning.

Therefore, a brief review of some of the pertinent literature on learning strategies for acquisition, retention, and transfer of skills will be provided. Applications will be made to the motor learning and verbal learning areas. Following this, we will take the position that it is not only the skills, per se, which should be transferred, but it is the knowledge of the methods for learning similar skills that actually needs to be acquired and transferred.

Facilitating Acquisition

The use of learner strategies to facilitate the acquisition of motor skills has not received much experimental attention. Self-imposed or externally-imposed strategies, however, must be analyzed and understood as to their contributions to the learning process. Verbal learning theorists (e.g., Belmont & Butterfield, 1971; Pask, 1975) have investigated the effects cognitive strategies have on the rate of learning and the amount of material learned. The conclusions have been unequivocal.

The application of mental operations which are compatible with a learner's cognitive capabilities have led to a superior level of skill attainment, when compared to persons who did not employ strategic operations. The implication for motor learning research is that the use of strategies during motor skill acquisition should enhance the learning process. However, until scientific inquiry into this area is undertaken to a substantial extent, inferences must be drawn from verbal learning research as to the potential beneficial effects of various types of strategies on the learning of skills.

Learning strategies have been shown to facilitate the storage as well as the retrieval of verbal information. Several types of strategies with which the acquisition of verbal information has been promoted are the learner's free choice of mnemonic techniques, various encoding instructions, or instructions in the use of particular strategies (Belmont & Butterfield, 1971; Bruner et al. , 1956; Craik & Lockhart, 1972; Craik & Tulving, 1975). The effectiveness of strategy utilization has been assessed through the length of interim pauses during list learning, response correctness during serial recall, and degree of semantic meaningfulness, or depth of processing. Although the measures differ, the conclusions drawn from these indices are similar. Strategies

have a facilitatory effect on the acquisition of information, and the more compatible the strategy is with the learner's cognitive capabilities, the greater the effect.

The facilitation effect is manifest in what Craik and Lockhart (1972) have termed Type II processing. Type II processing, in contrast to mere repetitive rehearsal, is a deeper, more elaborate analysis of the input that leads to a more durable trace. A rehearsal strategy of this kind increases the meaningfulness of the information through the identification of previously stored, similar material, and the combination of the new input with learned information. Elaborate processing appears to be the most significant method to enhance the acquisition of a task which requires a cognitive component (Craik & Lockhart, 1972; Weinstein, 1978). Rote repetition, or Type I processing, on the other hand, has been shown to be a less effective method for learning than elaboration strategies (Glanzer & Meinzer, 1967). Although a rehearsal strategy does serve to maintain information in STS beyond the normal decay period, the most important function of a rehearsal strategy seems to be to make information more manageable to facilitate its transfer from STS to LTS.

Control processes and memory strategies are used by

a learner to determine which information is entered and how it is registered into and eventually retrieved from long term memory storage (LTS). The sequence in which acquisition strategies are employed corresponds to the manner in which information is transmitted through the human behaving system. The strategies are invoked sequentially as information passes through the system. Thus, it is easy to identify the facilitatory effect a strategy may have on the processing efficiency of a learner who is rehearsing information in short term memory storage (STS).

A major function of the STS is to rehearse information so that greater meaning can be applied to it, and the information can be transferred easily to the LTS. Rehearsal strategies are often invoked to elaborate, to recode, or to transform selected inputs for future incorporation into a more stable internal code. Two of the most effective strategies for these information manipulations have been verbal elaboration (Weinstein, 1978) and imagery (Paivio, 1971). Both cognitive strategies enhance the durability of the active memory trace, as well as aid the learner in the transfer of information to LTS.

Perhaps the most efficient method of information transfer would involve the learner in the development

of organizational strategies. Use of these strategies seems to be a logical intermediary step between rehearsal and permanent storage, because previous memory chunks may have to be modified or revised based on the information in STS. Thus, organizational strategies would be employed by a learner to form interitem associations with current and previous memory stores to enhance the transfer of information from STS to LTS, thereby improving retention.

Facilitating Retrieval and Retention

Information which is stored effectively (i.e., well-organized) should be remembered well. If organization processes are to guarantee accurate recall performance, then transformational processes must occur during the organization and storage of learned material to enhance the probability that the information can be efficiently retrieved by STS from LTS at a later date. Retrieval (STS) presupposes storage (LTS), and a retrieval cue should only be effective if the material has been appropriately organized with the retrieval cue incorporated into the memory structure at the time of storage. The encoding specificity principle has received much empirical support (e.g., Tulving & Thomson, 1973; Watkins & Tulving, 1975), but there is not enough evidence at present from which a determination can be made if there are other means to

access memory in the absence of a particular retrieval cue. One conclusion which may be drawn, however, is that specificity of storage and retrieval cues is an important determinant of retention performance.

Retention is a function of the retrievability or irretrievability of an item. Information which has been stored in LTS is never truly forgotten. Instead, the memory circuits are probably inaccessible at the time of the retention test. This conclusion has been supported by Buschke (1973), who showed that words could eventually be retrieved from memory even after numerous recall failures. The recall failures were due to the learner's inability to retrieve the items, rather than forgetting, because retrieval and learning did finally occur without further presentations of the stimulus materials. Thus, recall performance (retention) is not only based on the storage of an item in LTS, but it is also the result of information storage that occurred in a distinctive mental context (Spear, 1976) so as to facilitate retrieval, given the proper cue.

Retention and retrieval are highly interrelated, as retrieval processes lead to a determination that information has been retained. It is important to demonstrate that performance on a retention test is a result of the interaction between strategies used for the

acquisition of a memory (representation) and the retrieval strategy associated with a stored item (Spear, 1976). However, the retrieval cue or orienting task must be unique in that it facilitates recall of information that has been acquired only in the given learning environment, and during no other time. For example, in a movement reproduction task, if a retrieval cue elicits recall of material that was not part of the present learning situation, but was acquired at an earlier date, the obtained retention results are obviously not a function of the learner's ability to retrieve newly learned information. The same results could be due to high probability guessing (Freund & Underwood, 1970), in which case performance scores on the retention test would not reflect the relationship between the retrieval strategy and the specific information which was to have been learned.

The possibility of one retrieval cue which leads to the recall of several acquired memories is not to be viewed too negatively, however. Multiple retrievals based on one recall strategy are contradictory to the encoding specificity principle which requires a unitary relationship between storage and retrieval processes for accurate retention performance. As such, the learning and retention of particular information specified by the cue would be increased, but the learning and retention

of other information which was presented in the same session would be reduced. This is not a desirable situation in motor skill acquisition because of the plethora of factors which may be operational during future performance. As a result, the encoding specificity principle seems to be severely limited in applicability, based on the present interpretation.

A more desirable learning environment would include a strategy which leads to multiple retrievals. The existence of such a strategy can be interpreted as evidence for the generalizability of a strategy to several tasks which have been or have to be learned as proposed in Figure 4. This would be in contrast to previous theoretical positions in motor learning of the specific nature of skill acquisition and its relationship to performance. Additionally, if one strategy can be generated which facilitates the retrieval of various acquired skills with common components, then it is probable that the same or a similar strategy can be used during acquisition as during retrieval. In other words, the strategy or cue a person uses that leads to the retrieval of different sources of information from LTS may be the same strategy that would enhance the placement of the information into LTS. In actuality, acquisition and retrieval strategies serve complementary functions. An

category: closed loop tasks

examples: archery pull

driving a car

basketball shooting

running



strategy: self-cueing the appropriate proprioceptive

information



improve feedback monitoring



effectors

Figure 4. Relationship between a category of tasks and one strategy.

acquisition strategy facilitates the storage of information into LTS from STS, and a retrieval strategy enhances the extraction of information from LTS to STS for active use. Thus, whereas the transfer of skills, especially motor skills, is often highly specific from task to task, as evidenced by the encoding specificity hypothesis, the transfer of strategies related to the acquisition and the retention of those skills may be more generalizable in that a single strategy may lead to multiple storage codes or multiple retrievals.

Facilitating Transfer

Cognitive strategies have been shown to facilitate the acquisition and retention of newly learned verbal skills (e.g., Campione & Brown, 1974) and motor skills (Hagenbeck, 1978; Ho & Shea, 1978; Shea, 1977), but the generalizability (transfer) of the strategies to other situational contexts has not been thoroughly investigated. While the short-term effects of strategy usage are well-known (e.g., Belmont & Butterfield, 1973), knowledge of the long-range effects is minimal. In fact, there is little supportive evidence that strategies used in one situation are applicable and facilitatory in a future situation (Brown, in press). However, it is our contention that strategies which enhance skill acquisition and short-term retention also have the potential to transfer to the

learning of a skill in a new situation with similar parameters.

Strategy transfer usually cannot occur unless the learning environment includes some reference to the transfer situation (Bransford, Franks, Morris, & Stein, 1978; Campione & Brown, 1974; Morris, Bransford, & Franks, 1977), e.g., the temporal structuring of the components within each task are similar (Keele & Summers, 1976). Another factor that has an influence on strategy generalizability is the compatibility of a particular strategy with a learner's cognitive processing capabilities. If a strategy is effective but incompatible, the learner would tend to reject it in lieu of some other, less efficient strategy. This less efficient strategy may facilitate initial acquisition, but it would probably have a detrimental effect in a transfer situation. The decrement in transfer learning would be the result of the limited applicability of the self-imposed strategy.

A solution to this dilemma is to train the learner in the principles of strategy usage in combination with an awareness of personal cognitive capabilities. Through this training, a learner will be able to identify all facets of a problem (i.e., a skill to be acquired) before proceeding to solve the problem. More importantly, the self-induced task analysis will have greater meaning

because the learner will be capable of structuring the input in an optimal manner to facilitate achievement of the final task goal (cf. Brown, in press). This is only possible when the learner acquires knowledge about memory or cognitive and motoric processes.

To train a person to be aware of the potential to activate strategies for skill acquisition is not sufficient. Externally imposed strategies will produce the same positive effect on immediate learning as will internally generated strategies. The training of this potential must also be geared to the utility of those abilities in future retention and transfer situations (Duncan, 1953). In this way, a person can enter new learning environments, acquire the necessary skills prescribed in that environment, and do so with a minimal amount of external guidance.

The major controversy in the teaching of strategies for transfer effectiveness appears to be whether to train people in the use of task-specific strategies, or to train learners in the more general applications of strategies related to rehearsal, storage, and retrieval, i.e., memory techniques. Researchers in verbal learning have addressed this problem from apparently dichotomous positions. Belmont and Butterfield (1977) contended that Brown (1974) supported the position that training task

specific strategies was most beneficial to learning, whereas Butterfield, Wambold, and Belmont (1973) stated that training should be designed toward the establishment of control processes within the memory system. The control processes would then regulate the activation of learning strategies (Singer & Gerson, in press). While the dichotomy is apparent, the distinction between the two positions may not be as clearly demarcated as first believed.

Brown (in press) concluded that it was difficult to conceive of a training program for the executive control of strategies without a set of strategies to control. The relationship between strategies and control processes was proposed to be of an interactive nature (Singer & Gerson, in press) in that strategies which were activated during a learning situation had to be controlled, monitored, or regulated. Thus, Brown's (in press) statement that the two theoretical positions were not polar opposites, because training of memorization skills must precede training in the regulation of strategic behaviors, was supported by the hierarchical relationship between strategies and control processes (Singer & Gerson, in press). Essentially, the major conclusion to be drawn is that preliminary memory skills must be trained before executive control functions can be studied.

The training of memory skills should not be geared

to individual, task specific learning strategies, but rather the training program should be designed to develop general problem-solving approaches (Scandura, 1966a, 1966b). Therefore, the learner should be taught to develop the mental processes that will lead to successful transfer task performance, whether or not the practice task resembles the transfer task (Blaiwes, Puig, & Regan, 1973). One technique is to provide a detailed task analysis along with various alternative strategies that may improve the rate of learning of each subcomponent of the task (Belmont & Butterfield, 1977; Singer & Gerson, in press).

This would allow the identification of a single, or a multiple, cognitive strategy that would be optimal for the rapid and efficient acquisition of skill. Thus, not only is it important that the learner obtain the task goal, but it is equally as important that the learner develop an awareness of the memory and motoric processes involved in achievement. Training in task specific strategies only results in task improvement without an increase in the learner's knowledge base so that the potential to transfer the techniques for acquisition to new situations is limited. However, when an understanding of the learning process is accomplished, transfer to new situations is realized.

For effective transfer to occur, both the instructor

and the learner must understand the original training task and the transfer task (Belmont & Butterfield, 1977; Morris et al., 1977). The components of both tasks must be similar enough so the learner is able to determine the relationship between the two tasks. Performance decrements on the transfer task are often due to the trainee's inability to comprehend these relationships, but inferior performance may be due to the differences between the demands of the two tasks which neither the instructor nor the learner realized (Brown, in press). When transfer is not demonstrated because of differential task requirements, it is not due to a deficiency in the learner's cognitive capabilities.

The lack of transfer is a result of the change in the processing activities required by the two tasks (Morris et al., 1977). Therefore, if the objectives of a training program are to effect generalizations of strategy usage across categories of tasks, then a thorough task analysis must be conducted on the original and the transfer learning tasks to identify physical as well as cognitive relationships. Subsequent to the task analysis, training should be geared toward those skills which have a broad application to a variety of verbal and motoric problem-solving situations, rather than to task specific strategies with limited potential for transfer (Eric, 1960;

Hendrickson & Schroeder, 1941; Judd, 1902; Overing & Travers, 1966).

A PSYCHOMOTOR TASK CLASSIFICATION SCHEME

The identification of the physical capabilities a learner must possess and the cognitive processes and the strategies a learner may employ to acquire a motor skill necessitates a determination of those strategies that should be matched with particular categories of tasks. That is, what type of organizational structure does the learner impose on the task information through the use of cognitive strategies, and how is the learner able to use this structure to facilitate the storage and retrieval of information for different tasks with similar characteristics? Tasks differ in the demands they place on a learner, and in the situational contexts in which they must be learned.

As such, the differing task requirements must be determined in order for the learner to structure the movement information inherent in these skills. Then, strategies which would enhance the skill acquisition process could be accurately identified in accordance with the components of each activity, or categories of activities. Ideally, a functional classification scheme of both skills and associated learning strategies would

be constructed, and this information could be useful in the development of more effective training programs.

We have constructed a psychomotor task classification system in accordance with our development and refinement of a model of motor behavior (Singer, Gerson, & Ridsdale, 1978), and the identification of cognitive processes, strategies, and interactive relationships associated with that model. Categories of motor tasks were identified on the basis of commonalities with regard to situational demands and accommodating responses. The need for a classification system was paramount because there is no adequate categorization scheme of psychomotor skills at the present time to facilitate the application of learner strategies. Furthermore, the results of experimental investigations in motor learning often lacked ecological validity (situational generalizability) because there was no unified conceptual framework within which researchers could work.

Previous Developments

Several attempts have been made toward the development of classification systems (Farrell, 1975; Gentile, Higgins, Miller, & Rosen, 1975) and taxonomies (Fleischman, 1967; Harrow, 1972; Simpson, 1966, 1972) for the psychomotor domain. A classification system is usually designed to describe and categorize behaviors that possess elements

in common or not in common. A taxonomy, in addition, includes a hierarchical progression of behaviors. Although researchers have often used the terms interchangeably, we have preferred to work toward a task classification scheme.

Of the taxonomies that have been developed, Fleishman (1967) has attempted to relate abilities to motor performance. Harrow (1972) has expanded this approach to include reflexive and basic movement patterns. They both acknowledged the role cognitive behaviors play in skilled performance, but, because the taxonomies were designed to help describe the physical processes of task performance, neither scholar attempted to explain the cognitive functions associated with motor behavior. Simpson (1966, 1972), however, characterized behavior in the psychomotor domain as reflective of the mental, emotional, and physical states of the performer. Indeed, the relationship among these three domains of behavior cannot be overlooked if skilled performance is to be described appropriately and effectively (Singer & Gerson, in press; Singer, Gerson, & Ridsdale, 1978).

The omission of descriptions about the relationships among the three domains of behavior has been a major limitation of the taxonomies of the psychomotor domain. Although instructors can identify task components and objectives, there have been no means to determine if and how

a learner might use strategies during skill acquisition. This problem was not overcome by the developers of classification systems for motor skills, even though several scholars considered the individual as an influential factor in performance outcome (e.g., Farrell, 1975; Gentile et al., 1975).

Farrell (1975) and Gentile et al. (1975) have provided comprehensive classification schemes related to gross motor and physical education skills. The Gentile et al. model appeared to be an extension of Farrell's work in that the former used refined kinematic procedures to facilitate task analyses while the latter was based on a task analysis by visual inspection. Both accounted for the environmental conditions surrounding the performance and the coordinated movement of the performer's limbs through space. The environmental demands most fully described in these schemes were self-paced, mixed-paced, and externally-paced, while some consideration was given to whether the task was performed with or without constant feedback.

Skilled performances occur at different speeds in varied environments. Open-loop tasks are performed so rapidly that performance outcome information can only be used after completion of the movement, due to processing delays (Keele, 1968; Kriefeldt, 1972). In contrast,

closed-loop skills occur at a slower pace thereby allowing a person to make intermittent adjustments during the performance, if necessary, through a match between feedback cues and an internal referent (Adams, 1971). Open skills (Gentile, 1972; Poulton, 1957) or externally-paced skills differ from these because a performer is required to anticipate and to make decisions about response adaptation in a brief period of time. The environment is dynamic, whereas in a closed skill (Gentile, 1972; Poulton, 1957) or a self-paced skill, the environment is stable and there is less of a concern for rapid perceptual adjustments and more of a need for the refinement of a specified sequence of responses (Kriefeldt, 1972; Singer, 1972, 1975).

The performance of a mixed-paced task involves more uncertainties in the situation than does the performance of a self-paced task, but the situation is only partially, not totally, dynamic; i.e., the learner is in motion but the object is not or the object is in motion while the performer is still. An example of this would be hitting a baseball. This is also a good example to use to distinguish between discrete and continuous tasks. The actual striking of the ball is a discrete task, there is a predetermined beginning and end. The complete swinging motion is continuous because there is

somewhat of an extended length of time between the initiation and completion of the task, and there are no recognizable breaks in the performance (Schmidt, 1975; Singer, 1975). However, these categories of tasks are not sufficient to facilitate a sophisticated task analysis that would lead to the identification of alternative learner strategies.

Although the descriptions of task components and pacing conditions help to contribute meaningfully to any classification scheme, to provide a method of task analysis to facilitate instruction, neither Farrell (1975) nor Gentile et al. (1975) fully considered the learner's cognitive involvement in the various activities. The learner/performer was the focal point of each scheme, but only the physical actions of the person were considered. The mental operations an individual would progress through and apply to learn or to perform a skill were not accounted for. Hence, the possibility that a learner may use strategies to facilitate skill acquisition could not be determined.

Rationale for a New Approach

In view of the limitations of previous classification schemes, we have developed a three factor task classification model that incorporates some previously identified factors, and some new ones. We have recognized

the concern evidenced in previous works for the environmental or pacing conditions surrounding a movement. Additionally, we have included the use of ongoing or terminal feedback as a distinguishing characteristic of skills. Although feedback (including knowledge of results) is a major determinant of skill acquisition, its influence has only been partially considered in the classification of skills through the distinction between open-loop and closed-loop tasks. The third factor in our scheme reflects the processing mechanisms within the human behaving system that have the greatest impact on the trainee's use of information inherent in a motor learning situation.

Our enumeration of the sensory-perceptual mechanisms, short and long-term stores, and the movement generator-effector mechanisms as the subcategories of this factor can be related to previous input-central processor-output distinctions (e.g., Marteniuk, 1976; Welford, 1968). However, we believe that a specific determination of the mechanisms facilitates the identification of strategies that will increase the processing effectiveness of each mechanism. Thus, our task classification scheme is based on (a) environmental conditions, (b) feedback availability utilization, and (c) the processing mechanisms that are most influential in performing manipulations of the information inherent in a task and situation.

The Proposed Task Classification Scheme

The three factor classification scheme, as illustrated in Figure 5, can be supported on theoretical grounds. The pacing conditions have been a concern of researchers who have attempted to improve task analysis procedures to enhance instruction (Gentile, 1972; Kriefeldt, 1972, Poulton, 1957). Each type of environmental demand requires a different arrangement of the learning environment to optimize skill acquisition (Singer, 1975). Thus, one would expect that strategies associated with a self-paced task would differ from those used with an externally-paced task. An example would be the need for more strategies for rapid decision-making in the externally-paced task which places a greater demand on the various processing mechanisms, while in the self-paced task, strategies for rapid decision-making are not essential.

The inclusion of the dominant cognitive mechanism or the type of operation that is performed on the information as a second category in the classification scheme is consistent with our model of motor behavior (Singer & Gerson, in press; Singer, Gerson, & Ridsdale, 1978). Although many more mechanisms were described in the model, it was not feasible to include all of them in the task classification scheme. As such, several mechanisms were combined to compose the categories of input operations,

FEEDBACK UTILIZATION		DOMINANT COGNITIVE MECHANISMS					
<u>Continual</u> (closed, ongoing)					<u>Terminal</u> (open, subsequent)		
		<u>Sensory-Perceptual Mechanisms</u> (input operations)	<u>Short & Long Term Storages</u> (central operations)	<u>Movement Generator & Generation</u> (output operations)	<u>Sensory-Perceptual Mechanisms</u> (input operations)	<u>Short & Long Term Storages</u> (central operations)	<u>Movement Generator & Generation</u> (output operations)
PACING REQUIREMENTS							
<u>Externally-Paced</u>							
<u>Mixed-Paced</u>							
<u>Self-Paced</u>							

Figure 5. Task classification scheme.

central operations, and output operations. This not only allowed us to adhere to the cognitive emphasis we have described during the learning of motor skills, but we were also able to maintain a degree of parsimony in the scheme. The description of tasks according to the processing load they place on particular mechanisms in the system further allows the identification of learner strategies.

The third factor that has been included in the scheme to improve the description of strategies is the utilization of feedback, either continuous or terminal (Holding, 1965). At what point during performance a learner uses feedback has been the basis of the dispute between closed-loop and open-loop theorists for years (Adams, 1971, 1976; Keele, 1968, 1973; Schmidt, 1975, 1976). If an individual employs feedback during a performance for error detection and correction, certain strategies should be more effective than if the learner must wait until the movement is completed to process the feedback. An open-loop skill places different demands on the trainee than does a closed-loop skill (Schmidt, 1975) which is another reason why strategy usage should differ.

The factorial task classification scheme is shown in Figure 5. The strategies that have presently been identified are more related to the processing category

than to the feedback and pacing conditions. This is because the latter two categories are quite restrictive in that they require very specific strategies in limited numbers. For example, an externally-paced, continuous feedback task such as hitting a tennis forehand may only involve the use of a strategy in which concentration is directed towards contacting the ball. However, if the strategies were identified in relation to the processing mechanisms a person must use to progress through the stages of hitting the tennis forehand, more strategies would be identified, and instruction would proceed more efficiently (cf. Pask, 1969).

The instructional sequence would begin with concentration and tracking strategies (input operations) to attend to the ball leaving the opponent's racket. Then, the learner would have to follow the ball to its bounce point while moving toward that spot, determine where to hit the ball in relation to the opponent's court position, and then decide how hard to strike the ball (central operations). The actual response would then be carried out and preparation for the next response would begin (output operations). If a learner has trouble with any one of these three areas, the strategies associated with each could be taught in isolation prior to the task components becoming an integrated whole.

This is the approach we have chosen to take at the present time. Tasks will be identified according to all three categories with the major emphasis placed on the processing demands. Then, strategies will be selected that have been shown to reduce the information loads and lead to faster skill acquisition. In future work, different strategies will be determined that relate more to the pacing and feedback conditions, but the current focus remains on the strategy-process relationship.

Strategies and Task Demands

A thorough search of the theoretical, experimental, and applied literature has enabled us to identify and to define several strategies that can be associated with task load demands that are primarily in the input, central processing, or output stages. These relationships are presented in the form of tabular material for simplification and ease in understanding the proposed relationships. Each processing demand stage is noted, along with the identification of processes and strategies. The strategies are then defined.

In Table 3, there are several cognitive processes associated with the sensory-perceptual mechanism, as well as several strategies for each that can potentially influence the processing of information and ultimately performance. For example, the set and orient strategies

Table 3
Input Operations: Sensory-Perceptual Mechanisms

Cognitive Processes	Possible Strategies
1. Influence receipt of sensory information.	1a. Set
	1b. Orient
2. Alert to situational possibilities, cues.	2a. Prepare
	2b. Anticipate
	2c. Guess
3. Selectively attend to information (filtration or attentuation).	3a. Scan
	3b. Focus
	3c. Concentrate on cues
	3d. Concentrate on movement
	3e. Defocus and divert attention
	3f. Switch
4. Identify-recognize relevant cues.	4a. Feature analyze
	4b. Classify
	4c. Categorize (cluster)

have been shown to influence perceptual and even memory performance in verbal skills (Rigney, 1978) when compared to no strategies. Similar beneficial effects may accrue from the use of such strategies with motor behaviors. Additionally, the numerous strategies associated with the selective attention process have been shown to facilitate the acquisition of both verbal and motor skills.

Those who have researched vigilance and tracking behaviors (e.g., Mackworth, 1950) have shown that the ability to adapt the focus of attention to changing stimuli leads to better performances than merely fixating on a particular cue. In studies of other selective attention processes, Henry (1960; Henry & Rogers, 1960) concluded that attention to either a sensory set or to a motor set enhanced performance based on the task demands. As another example, Stratton (1977) provided evidence for improved motor performance when a learner could re-allocate attention at the appropriate time as it was required by the task. Finally, feature analysis, classification, and categorization strategies have been shown to be effective during verbal learning (Neisser, 1967), but their applicability to motor behavior remains to be tested. The definitions of each of these strategies are provided in Table 4.

The processes and strategies associated with central

Table 4
Sensory-Perceptual Strategies Explained

1a.	<u>Set.</u>	Preparation of readiness to use appropriate sensory modality(ies) to receive information.
1b.	<u>Orient.</u>	Establishment of directional activity (focal point) that bears influence on the receipt of sensory information.
2a.	<u>Prepare.</u>	Free conscious capacity and perform ongoing skills in subconscious manner, and attend to minimal cues.
2b.	<u>Anti-cipate.</u>	Conscious energy directed toward potential subsequent task and situational occurrences, based on prior experiences and probability (objective prediction).
2c.	<u>Guess.</u>	Expectation of occurrences by subjective probability (intuition).
3a.	<u>Scan.</u>	The entire field (immediate task environment) viewed in an organized and systematic manner.
3b.	<u>Focus.</u>	The band width of attention narrowed or widened, depending on changing task demands.
3c.	<u>Sensory set.</u>	Attention directed to the immediate relevant cue(s) of the task.
3d.	<u>Motor set.</u>	Attention directed to the movement to be produced to a particular stimulus.

Table 4
(continued)

3e.	<u>Defocus.</u>	Attention focused away from the immediate task to avoid anxiety, tenseness, and fatigue.
3f.	<u>Switch.</u>	Reallocation of attention from cue to cue at appropriate time.
4a.	<u>Feature</u> <u>analyze.</u>	Initial level of meaning (contextual or physical arrangement) established for cue(s).
4b.	<u>Classify.</u>	Cues that are feature analyzed arranged according to a standard.
4c.	<u>Catego-</u> <u>rize.</u>	Clusters of cues arranged according to a common characteristic.

memory operations are indicated in Table 5. This area has been the most studied in the verbal and motor domains, and thus, the lists are extensive, but not exhaustive. To attempt to cite research to support each individual strategy choice for inclusion in the table would be an impossible task, so only representative examples will be given for each cognitive process.

Situational appraisal strategies such as task analysis (Gagné, 1977) and expectancy formation (Weiner, 1974) have been shown to facilitate present and future performances, both in verbal learning (Feather, 1969) and in motor learning (Gerson, 1978; McCaughan, 1976). Particular rehearsal strategies have been more effective than others during skill acquisition. Imagery and elaborative imagery have enhanced verbal learning (Paivio, 1971) and motor learning (Hagenbeck, 1978; Shea, 1977) when compared to rote repetition of the labeling of items. Singer has summarized the literature on the mental rehearsal of motor skills (Singer, 1975), and such rehearsal and chunking (Miller, 1956) strategies were demonstrated to be more effective during learning than the use of no particular strategy or a passive strategy (Belmont & Butterfield, 1973) in which a learner attempted to recall each item in a list individually.

Learning, or recall, has also been facilitated by

Table 5
Central Operations: Short and Long-term Storages

Cognitive Processes	Possible Strategies
1. Appraise situation and personal readiness state.	1a. Task analyze 1b. Self analyze 1c. Self inquire 1d. Form goal image 1e. Form performance expectancy 1f. Relax and concentrate 1g. Conserve energy
2. Process information for later use, to facilitate storage and retrieval.	2a. Image 2b. Elaborate image 2c. Implicitly verbalize 2d. Overtly verbalize 2e. Name 2f. Chunk 2g. Covertly (mentally) rehearse
3. Plan and select program execution (determine parameters in which movement is to operate).	3a. Search 3b. Match 3c. Compare 3d. Retrieve

different types of memory searches. Depending on the situation, a serial, terminal search, where the learner examines each item in memory in sequential order and then stops when the desired item is found, may be better than an exhaustive search, where the total memory store is explored before the examination process is terminated, even if the item is found early (Sternberg, 1969). When the stored information has been found, it must be retrieved. Tulving and Thomson (1973) have shown retrieval to be facilitated by a specific cue that was stored during acquisition, rather than merely through a random search of memory. These and other central operation strategies are described in Table 6.

The processes and strategies associated with movement generation are proposed in Table 7, and several of them were adapted from Glencross (1973; Note 1). The definitions are provided in Table 8. Glencross has suggested these strategies to be necessary components of response organization and skilled performance, but there is no research as to how instruction in one or several of these strategies would enhance motor behavior. The effects of these strategies need to be determined with regard to which strategy contributes the most to response organization. Much will probably depend on the nature of the task itself. Furthermore, the necessity

Table 6
Short and Long-term Strategies Explained

1a. <u>Task analyze.</u>	the nature, components, and demands of the task determined
1b. <u>Self analyze.</u>	personal competencies to achieve the task determined
1c. <u>Self inquire.</u>	personal readiness state to learn (perform) determined (motiva- tion, anxiety, concentration)
1d. <u>Form goal image.</u>	objectives of the task outcomes determined
1e. <u>Form performance expectancy.</u>	level of subjective probability of success established con- sidering task and personal analysis
1f. <u>Relax and concen- trate.</u>	the establishment of the ideal balance between relaxation and intense concentration
1g. <u>Conserve energy.</u>	energy demands (endurance, power, strength) of the task analyzed and supplied accordingly
2a. <u>Image.</u>	task pictured mentally
2b. <u>Elaborate image.</u>	task pictured mentally in a familiar setting, not neces- sarily in the present context

Table 6
(continued)

2c.	<u>Implicitly ver-</u> <u>balize.</u>	task rehearsed subvocally
2d.	<u>Overtly verbalize.</u>	task rehearsed aloud
2e.	<u>Name.</u>	task labeled for easier identification
2f.	<u>Chunk.</u>	sub-task coded into groupings
2g.	<u>Covertly rehearse.</u>	task execution practiced mentally
3a.	<u>Search.</u>	long-term store scanned for task related information
3b.	<u>Match.</u>	past experiences (successes and failures, performance demands) associated with present task
3c.	<u>Compare.</u>	present response parameters related to previous actions in similar situations

Table 6
(continued)

3d. <u>Retrieve.</u>	information recovered from LTS according to accessibility and availability
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Table 7
Output Operations: Movement Generator and Generation

Cognitive Processes	Possible Strategies
1. Organize behaviors.	1a. Develop individual response units 1b. Develop sequences of response units 1c. Develop phasing of units 1d. Develop gradation of units 1e. Time whole response 1f. Select appropriate total response 1g. Generate new response 1h. Control response
2. Utilize response-produced feedback.	2a. Awareness of feedback 2b. Activate sense modalities 2c. Detect errors and sources 2d. Determine magnitude of errors 2e. Correct errors 2f. Attribute 2g. Control personal behavior

Table 8
Movement Generator and Generation Strategies Explained

1a. Isolate response units	Concern for representation of forces for individual response units
1b. Sequence response units	Providing order to response units
1c. Phase	Timing of individual response units to each other (temporal structuring)
1d. Gradate	Gradating responses considering external forces (muscle force determined according to situational forces)
1e. Time	Entire response (all units) timed to a particular event
1f. Select appropriate response	Selection of appropriate response from existing ones
1g. Generate a new response	Knowing when and how to generate a new response
1h. Control	Controlling entire activity through automation or potential for modification and amendment
2a. Awareness of feedback	Determine what information feedback to pay attention to and what not to

Table 8
(continued)

2b. Activate sense modalities	Determine which sense modalities should be tuned to information feedback
2c. Detect errors and sources of errors	Determine deviations between performance and goal-image and causes
2d. Determine magnitude of errors	Focus on degree of qualitative and quantitative information feedback
2e. Correct errors	Modify ongoing or subsequent performance to minimize error discrepancy
2f. Attribute	Determine causations of performance as objectively as possible
2g. Control personal behavior	Locus of control over situation and behaviors internally directed instead of externally directed

for research in this area was underscored by Glencross' (Note 1) statement that skilled motor behaviors are a function of the stage of development of the cognitive structures controlling the actual actions. Thus, cognitive processes must be considered and used appropriately for a person to exhibit effective motor control.

Skilled performance is often evidenced by a learner's technique in the use of response-produced feedback. It should be pointed out that the cognitive process of feedback utilization, and strategies such as an awareness of certain cues that arrive at a specific modality or the formation of attributions may appear to be better related to input and central operations rather than to output operations. The use of feedback was considered as an output operation because it occurs after the response has been initiated, or completely terminated. As an example, a highly skilled performer knows which feedback cues are relevant and when they should be attended to, while the less skilled person may unnecessarily consider extraneous and irrelevant cues. This differential use of feedback does lead to differences in performance (Lawther, 1977).

Performance differences are related to learners' use of feedback cues that activate different sense modalities. Unless specifically instructed to attend

to kinesthetic cues, a person will concentrate on visual inputs to improve motor performance (Kelso, Cook, Olson, & Epstein, 1975; Posner, Nissen, & Klein, 1976). This is because vision is the dominant modality. However, in certain situations, attention to visual cues does not enhance performance. In fact, performance may even become impaired (Kelso & Frekany, 1978). Thus, it is imperative that explicit procedures be designed to control the allocation of attention to feedback cues in specific situations. Without this direction, learners will attend to vision, the dominant modality (Kelso et al., 1975), even when it is inappropriate to do so.

Attention to appropriate feedback cues is also important when a learner attempts to determine the location or distance of a performance error. Many researchers (e.g., Stelmach, Kelso, & Wallace, 1975) have shown location to be a more effective cue than distance for motor performance. As such, a learner should not always be concerned with how much the performance deviated from the goal-image, but the learner may want to consider the relationship between the termination points of the performance and criterion goal. Again, attention to appropriate feedback cues would be dictated by the situation and task, as when concentration must be directed toward a specific sense modality.

The use of feedback is a potent variable in motor skill acquisition. We know that strategies for feedback utilization can only be activated after the response has been initiated. However, the use of other strategies, such as situational appraisal strategies, does not always occur in the order described previously; i.e., input, central, and output operations. On the contrary, the placement of strategies in relation to the task classification scheme is not necessarily in the same sequence a learner would invoke these strategies during an instructional period. More precisely, several of the strategies would occur prior to, during, or after the performance. In future work, we hope to categorize strategies according to their temporal occurrence in the learning sequence, and then combine this with the task classification scheme. The integration of the two would then serve to facilitate designs of instructional methodologies for any type of task.

FUTURE DIRECTIONS

We have identified a number of potential learning strategies that are apparently associated with particular cognitive processes, which in turn are postulated to be related to certain mechanisms in the human behaving system. We are continuing to make a clearer identification

of the types of preferred learning strategies a person uses to acquire a motor skill, and this activity has revealed commonalities with verbal learning strategies, as well as unique considerations for motor learning.

The objective of our work is to eventually describe a minimal number of effective strategies unique to the learning of different categories of psychomotor skills. Presumably, when the learner deploys the best strategies, the functional capabilities of a given mechanism are enhanced, thereby increasing the rate of skill acquisition. However, the identification of strategies related to classes of psychomotor skills can only occur after further refined analysis of strategies and tasks. This will be done through extensive laboratory and field experimentation.

Experiments

Based on the relationships between strategies and tasks identified within the classification scheme, a series of laboratory experiments have been and will be designed. The purpose of these investigations will be to determine which alternative strategies that are available for a learner to use would be best suited to learn a particular class of motor skills.

For example, a student could be provided with alternative strategies for learning a ballistic, open-looped,

self-paced response. An analysis of performance would help to determine which strategy resulted in the fastest rate of acquisition. Then, this strategy would be used in the learning of another task which would be in the same response class (e.g., Schmidt, 1975). If the strategy is appropriate, it should generalize effectively to the learning of the new skill, as well as to other skills in the same task category.

An example of a psychomotor task in which the student is required to employ cognitive strategies involves serial learning. To acquire skill, a person must make a series of responses in appropriate sequential order. Various instructional techniques, such as prompting or problem-solving, may be used to guide the acquisition of a serial skill. Several methods for the investigation of the acquisition of serial responses have been employed in our laboratory using both manual (Hagenbeck, 1978) and computer-controlled tasks (Singer & Gaines, 1975; Singer & Pease, 1976).

The analysis of learning strategies in serial skill acquisition will be conducted using two tasks under the control of the experimenter. The tasks have been selected because they both involve a reasonable amount of cognitive activity and motoric responses, albeit in increasing degrees of complexity. The card sorting task requires

less cognitive involvement and less precision movement on the part of the learner than does the serial re-positioning task. Additionally, these tasks were chosen for experimentation because they demand the use of memory for learning, more so than strict motor output tasks such as punching a bag or moving a slide very rapidly to a mechanical stop.

Subjects in these experiments will be required to learn a sequence of responses under different strategy conditions. Half the subjects in each group will be taught only how to use the strategy for the experimental task, while the other half will be taught the principles of strategy usage prior to instruction in the application of a specific strategy. Then, their level of skill acquisition on the tasks will be determined through time to completion and error measures.

The effectiveness of acquisition strategies will be determined during the learning phase. It is expected that certain strategies will differentially influence skill acquisition, while other strategies will have more long-term effects (Singer & Pease, 1976). For this reason, the efficiency of strategy usage will not only be examined in an immediate acquisition situation, but the facilitatory nature of strategies will also be tested in delayed retention and transfer situations in

self-paced response. An analysis of performance would help to determine which strategy resulted in the fastest rate of acquisition. Then, this strategy would be used in the learning of another task which would be in the same response class (e.g., Schmidt, 1975). If the strategy is appropriate, it should generalize effectively to the learning of the new skill, as well as to other skills in the same task category.

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directions other investigators (Brown, in press; Morris et al., 1977) have taken in the cognitive area. Several of the strategies that were effective during learning may not be as influential during retention and transfer, but those that positively affect the later test situations will attest to the generalizability of strategy usage.

Strategy generalization to tasks with similar components is the second major factor of these experiments, following the facilitation of skill acquisition through strategy usage. The transferability of strategies will be tested on another task that requires the learner to respond to stimuli by making manipulative responses in a serial order. Testing will be done with the Serial Manipulation Apparatus (SMA) (Singer, 1976), which is a computer-controlled task in which the student must respond to auditory or visual stimuli by manipulating corresponding buttons, knobs, or switches. Additionally, the device may be programmed so that foot pedal responses are required, either separately or in conjunction with the hand movements. Students' responses can be measured according to time to complete the sequence correctly or as to the number of errors committed. It is believed that this particular task can be designed to simulate motor skill acquisition in real-world situations. Furthermore, the computer helps to provide desirable controls.

The programming capabilities which accompany a task of this type allow for many variations. The presentation rate of the sequence can be increased or decreased, the number of responses in the sequence can be changed from trial to trial, and the sequence itself can be randomly or consistently presented on each trial. The potential that these variations provide for examining psychomotor skill acquisition is enormous. Furthermore, as other variations are designed, more sophisticated experiments can be arranged in which the relationships between learner strategies, task type, and skill acquisition are investigated. The findings in these experiments will suggest instructional procedures for learning modules that describe methods for the development of self-management skills, or learner initiated, strategies to undertake and to achieve in various situations.

The Development of Learner Modules and Handbooks

Learner strategy modules will be developed based on the results of the experimental investigations and related supportive literature. Strategies will have been identified as applicable to a number of learning situations. Therefore, the generalizability of a strategy will be the primary determinant of its inclusion in a module. Consequently, it is intended that any module will hold implications for present task mastery as well

as for accomplishments in other related tasks potentially confronted by the learner in the future. These modules will then have to be field tested to confirm the results of the laboratory investigations and the effectiveness of the modules.

If the experimental tasks truly simulated real-world situations, the field research results should be confirmatory of the laboratory findings. The effectiveness of the modules will be observed following the development of specific evaluative procedures. Two levels of evaluation of each module are desirable. One is more immediate, the other more long-term. In answer to the question, "Are the modules teaching the learners the strategies they are supposed to?", evaluations will be made during the instructional program. To answer the question, "Are the learners better able to acquire psychomotor skills as a result of these experiences?", analyses must be made in a particular setting. The long-term evaluation of field performance is most desirable. On the basis of feedback received from field data, the modules will be revised, where necessary, and made more functional.

One particular evolution of our work that will have a great deal of functional utility will be a learning strategies handbook. This handbook will essentially be a cookbook approach for learners to the acquisition of

skill. Strategies will be described along with their relationships to categories of psychomotor tasks, and learners will be instructed in the development and use of these strategies. Self-checking and self-testing procedures will be included to ensure the learner that the strategies are actually being acquired and used, both in the module learning sessions and in other, related situations.

The handbook will probably contain more strategies than a trainee would need to use to acquire a particular skill, so it will not be necessary for the learner to complete all the material prior to entrance into a learning situation. As with all modules and handbooks, the time required to complete this learner strategy handbook will vary, depending on the content material in relation to the trainee's capabilities.

The primary goal is to aid learners in achieving a high level of skill in a minimal amount of time, at a minimal expense, with minimal instructor-learner interactions (self-learning), and with materials that create an enjoyable and motivating atmosphere. The final objective is to leave the learners with the capabilities to employ these generalizable strategies in new, but related, learning situations.

Practical Implications

Although the foundations for these efforts will be derived from theoretical perspectives, the focus of the material is toward practical applications. The identification of learner strategies, the instruction in the methods for the development and utilization of these strategies, and the production of learning modules can all be designed for both the instructor and the trainee. Through the final product of this work, the learning modules and handbooks, we hope to assist learners to speed up the skill acquisition process by using appropriate strategies. Furthermore, the use of several of these strategies will also increase retention and facilitate transfer learning in new, but related situations.

The implementation of strategies to improve acquisition, to enhance retention, and to increase transfer potential will have other beneficial effects on training programs. The length of training and review sessions will decrease because of the facilitatory nature of strategies. The decrease in time will then lead to a decrease in cost expenditures to train personnel. Additionally, the use of modules requires less involvement by instructors during the learning curriculum, so these highly trained personnel would be free to accomplish

other tasks. Finally, strategy usage will lead to more meaningful learning because the trainee will be more involved with the material.

Thus, the theoretical bases of strategy utilization described in previous sections of this report leads to sound, real-world practices. External guidance of learning environments will be minimized, while learner involvement will be maximized. The cost and time allotted for training programs will be decreased, but the long-term benefits of these programs will increase.

Necessity for Continued Research

It is an established fact that strategies facilitate the acquisition of verbal skills (Belmont & Butterfield, 1973; Brown, in press) and motor skills (Hagenbeck, 1978; Ho & Shea, in press; Shea, 1977). However, these strategies have been shown to be applicable only during initial learning and short-term retention. The effect of acquisition strategies on long-term retention and transfer has yet to be established. Furthermore, the relationship between strategies and classes of psychomotor tasks still needs to be established.

The strategies utilized in the studies cited above were task-specific, designed to improve the acquisition and the retention of a particular motor skill, e.g., serial positioning. There was no attempt to examine the

strategies under conditions that involved other tasks of a serial nature. Additionally, no determination has as yet been made as to the beneficial effects of instruction in strategy usage; i.e., how and why strategies should be used during learning, compared to the effects of instruction in the use of a particular strategy. We propose that while initial acquisition may be better under the latter condition, retention and transfer possibilities would be enhanced by the former training procedure (cf. Singer & Pease, 1976). Thus, continued research in strategy deployment and motor behavior, and with regard to the best way to instruct learners to develop and to implement strategies, is a vital necessity.

The need for future research on strategy development was further emphasized by Morris et al. (1977), who showed that retention and transfer of verbal skills was a function of the similarity between the test situation and the acquisition strategy. When a difference existed, decrements in performance occurred. It is necessary for motor skills researchers to show that, while skill to skill transfer may be task or situation specific, strategy transfer in motor behavior is generalizable. However, this would not be a finding unique to motor skills, as Brown (in press) has reported findings that

were indicative of strategy transfer among verbal skills. Thus, a major contribution of future research into strategy usage in motor skills would be to show that strategies which enhance acquisition and retention of a skill in one situation are generalizable to another skill with similar components in a different situation. Once again, the emphasis is not on task-specific or situational context transfer (Campion & Brown, 1974), but instead on the use of strategies across various situations.

SUMMARY

We have conducted an extensive review of the verbal and motor learning literature to facilitate the identification and understanding of learner strategies that aid in the acquisition, retention, and transfer of skills. The review has enabled us to define and to describe those cognitive processes that may be activated through the use of a particular strategy. Through the strategy-process relationship, we determined many of those strategies that are relevant to the learning of categories of psychomotor skills.

This led to a secondary aspect of the present work. We have provided a preliminary schematic for the classification of psychomotor tasks and strategies associated with categories of tasks. The tasks were categorized

according to the environmental pacing, information-processing, and feedback demands they placed on the learner, while the strategies were grouped according to the tasks that might be learned effectively when that strategy is employed. It was noted that one strategy was capable of being applicable to the learning of several tasks, which was interpreted as descriptive evidence for the generalizability of strategy usage.

Experiments have and are being designed to test the effectiveness of strategy usage across tasks of increasing cognitive and motoric complexity. These experiments are also designed to determine the most efficient method for instruction in strategy usage. A supplemental result of the experiments will be the validation of the relationship between the task and the strategy classification schemes.

Extrapolation from these results will be useful in the development of self-instructional modules and handbooks for training programs. This material will enable learners to progress through a training session with a minimal amount of external guidance, while both the cost and the time of administration of the training program should be decreased. The effectiveness of modular (self-learning) instruction will hopefully reaffirm the expected results of our laboratory experiments.

Our present and subsequent efforts were and are geared to: (1) identify the optimal learner strategies for the acquisition, retention, and transfer of classes of strategies and motor skills; (2) develop methods to teach learners the importance of strategy usage, how to acquire them, and then how to invoke a particular strategy when it is appropriate; (3) determine, through experimentation, the relationships between strategies and classes of motor skills so that the acquisition, retention, and transfer of these strategies and skills will be enhanced; (4) organize and field test learner modules for skill acquisition; and (5) refine the current theoretical framework through our experiments and constant monitoring of current literature.

The primary intent of our efforts is not designed to improve the acquisition of specific motor skills. Rather, we are seeking to develop methods which will enable learners to self-generate problem-solving strategies and techniques in order that skills may be obtained more rapidly. The development of analytical and adaptation processes within a learner will lead to the creation of self-instructional environments. If the trainee possesses the strategies and skills to produce a solution to a problem, then the amount of external guidance necessary for learning is reduced.

Additionally, the acquired skill is probably retained to a greater degree since the learner was more involved in the learning experience.

We hope to continually bridge the motor and verbal learning areas, as there are many human mechanisms and processes that operate similarly for all behaviors. Thus, although we will be analyzing ways of improving performance in motor behaviors, many findings should be applicable to verbal behaviors. Our conclusions are and should be applicable and of benefit to military, occupational, athletic, and educational training programs.

REFERENCE NOTES

1. Glencross, D. J. Output and response processes in skilled performance. Paper presented at the annual meeting of the North American Society for the Psychology of Sport and Physical Activity, Tallahassee, Florida, 1978.

REFERENCES

- Adams, J. A. A closed-loop theory of motor learning. Journal of Motor Behavior, 1971, 3, 111-150.
- Adams, J. A. Issues for a closed-loop theory of motor learning. In G. E. Stelmach (Ed.), Motor control: Issues and trends. N. Y.: Academic Press, 1976.
- Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), The psychology of learning and motivation (Vol. 2). N. Y.: Academic Press, 1968.
- Baldwin, T. L., & Garvey, C. J. Components of accurate problem-solving communications. American Educational Research Journal, 1973, 10, 39-48.
- Battig, W. F. Within-individual differences in "cognitive" processes. In R. L. Solso (Ed.), Information processing and cognition: The Loyola symposium. Hillsdale, N. J.: Erlbaum, 1975.
- Belmont, J. M., & Butterfield, E. C. Learning strategies as determinants of memory deficiencies. Cognitive Psychology, 1971, 2, 411-420.
- Belmont, J. M., & Butterfield, E. C. The instructional approach to developmental cognitive research. In R. Kail & J. Hagen (Eds.), Perspectives on the development of memory and cognition. Hillsdale,

- N. J.: Erlbaum, 1977.
- Blaiwes, A. S., Puig, J. A., & Regan, J. J. Transfer of training and the measurement of training effectiveness. Human Factors, 1973, 15, 523-533.
- Bousfield, W. A. The occurrence of clustering in the recall of randomly arranged associates. Journal of General Psychology, 1953, 49, 229-240.
- Bower, G. H. Organizational factors in memory. Cognitive Psychology, 1970, 1, 18-46.
- Bransford, J. D., Franks, J. J., Morris, C. D., & Stein, B. S. Some general constraints on learning and memory research. In F. I. M. Craik & L. S. Cermak (Eds.), Levels of processing and theories of memory. Hillsdale, N. J.: Erlbaum, 1978.
- Brown, A. L. The role of strategic behavior in retardate memory. In N. R. Ellis (Ed.), International review of research in mental retardation (Vol. 1). N. Y.: Academic Press, 1974.
- Brown, A. L. The development of memory: Knowing, knowing about knowing, and knowing how to know. In H. W. Reece (Ed.), Advances in child development and behavior (Vol. 10). N. Y.: Academic Press, 1975.
- Brown, A. L. Knowing when, where, and how to remember: A problem of metacognition. In R. Glaser (Ed.), Advances in instructional psychology. Hillsdale,

- N. J.: Erlbaum, in press.
- Bruner, J. S. The act of discovery. Harvard Educational Review, 1961, 31, 21-32.
- Bruner, J. S., Goodnow, J. J., & Austin, G. A. A study of thinking. N. Y.: John Wiley & Sons, Inc., 1956.
- Buschke, H. Selective reminding for analysis of memory and learning. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 543-550.
- Butterfield, E. C., & Dickerson, D. J. Cognitive theory and mental development. In N. R. Ellis (Ed.), International review of research in mental retardation (Vol. 3). N. Y.: Academic Press, 1976.
- Campione, J. C., & Brown, A. L. The effects of contextual changes and degree of component mastery on transfer training. In H. W. Reese (Ed.), Advances in child development and behavior. N. Y.: Academic Press, 1974.
- Chi, M. T. H. Short-term memory limitations in children: Capacity or processing deficits? Memory and Cognition, 1976, 4, 559-572.
- Craik, F. I. M., & Lockhart, R. S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.
- Craik, F. I. M., & Tulving, E. Depth of processing and the retention of words in episodic memory. Journal

of Experimental Psychology: General, 1975, 104,
268-294.

Cronbach, L. J., & Snow, R. E. Aptitudes and instructional
methods. N. Y.: Irvington Publishers, Inc., 1977.

Dansereau, D. The development of a learning strategies
curriculum. In H. F. O'Neil (Ed.), Learning strategies
I. N. Y.: Academic Press, 1978.

Duncan, C. P. Transfer in motor learning as a function
of degree of first-task learning and intertask
similarity. Journal of Experimental Psychology,
1953, 45, 1-11.

Ervin, S. M. Transfer effects of learning a verbal
generalization. Child Development, 1960, 31, 537-
554.

Estes, W. K. Learning theory and mental development.
N. Y.: Academic Press, 1970.

Estes, W. K. Handbook of learning and cognitive processes.
Hillsdale, N. J.: Erlbaum, 1975.

Farrell, J. E. The classification of physical education
skills. Quest, 1975, 14, 63-68.

Feather, N. T. Attribution of responsibility and valence
of success and failure in relation to initial
confidence and task performance. Journal of
Personality and Social Psychology, 1969, 13, 129-144.

Fleishman, E. A. Performance assessment on an empirically

- derived task taxonomy. Human Factors, 1967, 9, 349-366.
- Freund, J. S., & Underwood, B. J. Restricted associates as cues in free recall. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 136-141.
- Flavell, J. H., & Wellman, H. M. Metamemory. In R. V. Kail & J. W. Hagen (Eds.), Perspectives on the development of memory and cognition. Hillsdale, N. J.: Erlbaum, 1977.
- Gagne, R. M. Learning and individual differences. Columbus, Ohio: Charles E. Merrill Books, Inc., 1967.
- Gagne, R. M. Conditions of learning. N. Y.: Holt, Rinehart & Winston, 1977.
- Gagne, R. M., & Briggs, L. Principles of instructional design. N. Y.: Holt, Rinehart & Winston, 1974.
- Gentile, A. M. Short-term retention of simple motor acts. (Doctoral dissertation, Indiana University, 1967.) Dissertation Abstracts International, 1967-1968, 28, 2986-A (University Microfilms No. 68-49650).
- Gentile, A. M. A working model of skill acquisition with application to teaching. Quest, 1972, 17, 3-23.
- Gentile, A. M., Higgins, J. R., Miller, E. A., & Rosen, B. M. The structure of motor tasks. Mouvement,

- Journal of Educational Psychology, 1941, 32, 205-213.
- Henry, F. M. Influence of motor and sensory sets on reaction latency and speed of discrete movements. Research Quarterly, 1960, 31, 459-468.
- Henry, F. M., & Rogers, D. E. Increased response latency for complicated movements and a "memory drum" theory of neuromuscular reaction. Research Quarterly, 1960, 31, 448-458.
- Ho, L., & Shea, J. B. Levels of processing and the coding of position cues in motor short-term memory. Journal of Motor Behavior, 1978, 10, 113-121.
- Holding, D. H. Principles of training. Oxford: Pergamon Press, 1965.
- Hunt, E., & Lansman, M. Individual differences. In W. K. Estes (Ed.), Handbook of learning and cognitive processes. Hillsdale, N. J.: Erlbaum, 1975.
- Johnson, J. H. Memory and personality: An information processing approach. Journal of Research in Personality, 1974, 8, 1-32.
- Jones, B. Outflow and inflow in movement duplication. Perception and Psychophysics, 1972, 12, 95-96.
- Jones, B. Role of central monitoring of efference in short-term memory for movements. Journal of Experimental Psychology, 1974, 102, 37-43.
- Jones, J. G. Automation of skill: Its pros and cons.

- In U. Simri (Ed.), Motor learning in physical education and sport. Natanya, Israel: Wingate Institute for Physical Education and Sport, 1976.
- Judd, C. H. Practice and its effects on the perception of illusions. Psychological Review, 1902, 9, 27-39.
- Kausler, D. H. Psychology of verbal learning and memory. N. Y.: Academic Press, 1974.
- Keele, S. W. Movement control in skilled motor performance. Psychological Bulletin, 1968, 70, 387-403.
- Keele, S. W. Attention and human performance. Pacific Palisades, Ca.: Goodyear Publishing Co., 1973.
- Keele, S. W., & Summers, J. J. The structure of motor programs. In G. E. Stelmach (Ed.), Motor control: Issues and trends. N. Y.: Academic Press, 1976.
- Kelso, J. A. S. Planning and efferent components in the coding of movement. Journal of Motor Behavior, 1977, 9, 33-48.
- Kelso, J. A. S., & Stelmach, G. E. Central and peripheral mechanisms in motor control. In G. E. Stelmach (Ed.), Motor control: Issues and trends. N. Y.: Academic Press, 1976.
- Kelso, J. A. S., Cook, E., Olson, M. E., & Epstein, W. Allocation of attention and the locus of adaptation to displaced vision. Journal of Experimental Psychology: Human Perception and Performance, 1975,

1, 237-245.

- Kelso, J. A. S., & Frekany, G. A. Coding processes in preselected and constrained movements: Effect of vision. Acta Psychologica, 1978, 42, 145-161.
- Kennedy, C. B., & Butter, E. J. Cognitive style in two modalities: Vision and audition. Journal of Educational Psychology, 1978, 70, 193-199.
- Kriefeldt, I. G. A dynamic model of behavior in a discrete open-loop self-paced motor skill. IEEE Transactions on Systems, Man, and Cybernetics, 1972, 2, 262-273.
- Laabs, G. E. Retention characteristics of different reproduction cues in motor short-term memory. Journal of Experimental Psychology, 1973, 100, 168-177.
- Mackworth, N. H. Researches on the measurement of human performance. Medical Research Council Special Report Series No. 268. London: H. M. S. O., 1950.
- Mandler, G. Organization and memory. In J. T. Spence & K. W. Spence (Eds.), The psychology of learning and motivation (Vol. 1). N. Y.: Academic Press, 1967.
- Marteniuk, R. G. Retention characteristics of motor short-term memory cues. Journal of Motor Behavior, 1973, 5, 312-317.
- Marteniuk, R. G. Individual differences in motor performance and learning. In J. H. Wilmore (Ed.), Exercise and sport sciences reviews (Vol. 2).

- N. Y.: Academic Press, 1974.
- Marteniuk, R. G. Information processing in motor skills.
N. Y.: Holt, Rinehart & Winston, 1976.
- McCaughan, L. R. Performance as a function of attribution, expectancy, and achievement motivation, induced by two feedback conditions during learning of a novel motor task. Unpublished doctoral dissertation, Florida State University, 1976.
- Miller, G. A. The magical number seven plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-96.
- Morris, C. D., Bransford, J. D., & Franks, J. J. Levels of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 1977, 16, 519-533.
- Nacson, J. Effects of order presentation on arm positioning accuracy. Unpublished doctoral dissertation, Teachers College, Columbia University, 1974.
- Nacson, J., Jaeger, M., & Gentile, A. M. Organizational processes in short-term memory. In I. D. Williams & L. M. Wankel (Eds.), Proceedings of the Fourth Canadian Psychomotor Learning and Sports Psychology Conference. Ottawa, Canada: Department of National Health & Welfare, 1973.
- Neisser, U. Cognitive psychology. N. Y.: Appleton-

Century-Crofts, 1967.

Newell, A., & Simon, H. A. Human problem solving.

Englewood Cliffs, N. J.: Prentice-Hall, 1972.

Norman, D. A. Memory, knowledge, and the answering of questions. In R. Solso (Ed.), Contemporary issues in cognitive psychology: The Loyola symposium.

Washington, D. C.: Winston, 1973.

Norman, D. A., & Ramehart, D. E. Explorations in cognition. San Francisco: W. H. Freeman & Co., 1975.

Overing, R. L. R., & Travers, R. M. W. Effect upon transfer of variations in training conditions. Journal of Educational Psychology, 1966, 57, 179-188.

Paivio, A. Imagery and verbal processes. N. Y.: Holt, Rinehart & Winston, 1971.

Pask, G. Strategy, competence and conversation as determinants of learning. Programmed Learning, 1969, Oct., 250-267.

Pask, G. The cybernetics of human learning and performance. London: Hutchinson & Co., 1975.

Pew, R. W. Human perceptual-motor performance. In B. H. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. Hillsdale, N. J.: Erlbaum, 1974.

Posner, M. I. Cognition: An introduction. Glenview, Ill.: Scott, Foresman & Company, 1973.

Posner, M. I., Nissen, M. J., & Klein, R. M. Visual

- dominance: An information-processing account of its origins and significance. Psychological Review, 1976, 83, 157-171.
- Poulton, E. C. On prediction in skilled movements. Psychological Bulletin, 1957, 54, 467-478.
- Reitman, W. What does it take to remember? In D. A. Norman (Ed.), Models of human memory. N. Y.: Academic Press, 1969.
- Richardson, F. Behavior modification and learning strategies. In H. F. O'Neil, Jr. (Ed.), Learning strategies I. N. Y.: Academic Press, 1978.
- Rigney, J. W. Learning strategies: A theoretical perspective. In H. F. O'Neil, Jr. (Ed.), Learning strategies I. N. Y.: Academic Press, 1978.
- Roy, E. A., & Diewert, G. L. Encoding of kinesthetic extent information. Perception and Psychophysics, 1975, 17, 559-564.
- Scandura, J. M. Algorithm learning and problem solving. Journal of Experimental Education, 1966, 34, 1-6. (a)
- Scandura, J. M. Problem solving and prior learning. Journal of Experimental Education, 1966, 34, 7-11. (b)
- Scandura, J. M. Structural approach to instructional problems. American Psychologist, 1977, 32, 33-53.
- Schaeffer, B. Skill integration during cognitive development. In A. Kennedy & A. Wilkes (Eds.), Studies

- in long term memory. N. Y.: John Wiley & Sons, 1975.
- Schmidt, R. A. A schema theory of discrete motor skill learning. Psychological Review, 1975, 82, 225-260.
- Schmidt, R. A. Control processes in motor skills. In J. Keogh & R. S. Hutton (Eds.), Exercise and sport sciences reviews (Vol. 4). Santa Barbara, Ca.: Journal Publishing Affiliates, 1976.
- Shea, J. B. Effects of labeling on motor short-term memory. Journal of Experimental Psychology: Human Learning and Memory, 1977, 3, 92-99.
- Simon, H. A. The functional equivalence of problem solving skills. Cognitive Psychology, 1975, 7, 268-288.
- Simpson, E. J. The classification of educational objectives: Psychomotor domain. Urbana, Ill.: University of Illinois Press, 1966.
- Simpson, E. J. The classification of educational objectives in the psychomotor domain. In National Special Media Institute (Ed.), The psychomotor domain: A resource book for media specialists. Washington, D. C.: Gryphon House, 1972.
- Singer, R. N. The psychomotor domain: Movement behavior. Philadelphia: Lea & Febiger, 1972
- Singer, R. N. Motor learning and human performance (2nd ed.). N. Y.: Macmillan, 1975.
- Singer, R. N., & Gaines, L. Effect of prompted and trial-and-error learning on transfer performance of a

- serial motor task. American Educational Research Journal, 1975, 12, 295-403.
- Singer, R. N., & Gerson, R. F. Strategies, cognitive processes, and the acquisition of skill. In H. F. O'Neil, Jr. (Ed.), Learning strategies II. N. Y.: Academic Press, in press.
- Singer, R. N., Gerson, R. F., & Ridsdale, S. A conceptual orientation to the study of motor behavior. Technical Report 1 of the Motor Behavior Resource Center of Florida State University, Tallahassee, Florida, 1978.
- Singer, R. N., & Pease, D. The effect of different instructional strategies on learning, retention and transfer of a serial motor task. Research Quarterly, 1976, 47, 788-796.
- Spear, N. E. Retrieval of memories: A psychobiological approach. In W. K. Estes (Ed.), Handbook of learning and cognitive processes (Vol. 4): Attention and memory. Hillsdale, N. J.: Erlbaum, 1976.
- Stelmach, G. E., Felso, J. A. S., & McCullagh, P. D. Preselection and response biasing in short-term motor memory. Memory and Cognition, 1976, 4, 62-66.
- Stelmach, G. E., Kelso, J. A. S., & Wallace, S. A. Preselection in short-term motor memory. Journal of Experimental Psychology: Human Learning and Memory, 1975, 1, 745-755.

- Stratton, R. K. Developmental aspects of attention in the motor skill performance of children.
Unpublished doctoral dissertation, Florida State University, 1977.
- Trabasso, T. Discussion of the papers by Bransford and Johnson; and Clark, Carpenter, and Just: Language and cognition. In W. G. Chase (Ed.), Visual information processing. N. Y.: Academic Press, 1973.
- Tulving, E. Subjective organization in free recall of "unrelated words." Psychological Review, 1962, 69, 344-354.
- Tulving, E. Theoretical issues in free recall. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N. J.: Prentice-Hall, 1968.
- Tulving, E., & Thomson, D. M. Encoding specificity and retrieval processes in episodic memory. Psychological Review, 1973, 80, 352-373.
- Watkins, M. J., & Tulving, E. Episodic memory: When recognition fails. Journal of Experimental Psychology: General, 1975, 104, 5-20.
- Weiner, B. Achievement motivation and attribution theory. Morristown, N. J.: General Learning Press, 1974.
- Weinstein, C. Elaboration skills as a learning strategy.

In H. F. O'Neil, Jr. (Ed.), Learning strategies I.

N. Y.: Academic Press, 1978.

Welford, A. T. Fundamentals of skill. London:

Methuen, 1968.

Witkin, H. A., & Goodenough, D. R. Field-dependence

revisited. Research Bulletin 77-17. Princeton,

N. J.: Educational Testing Service, December, 1977.